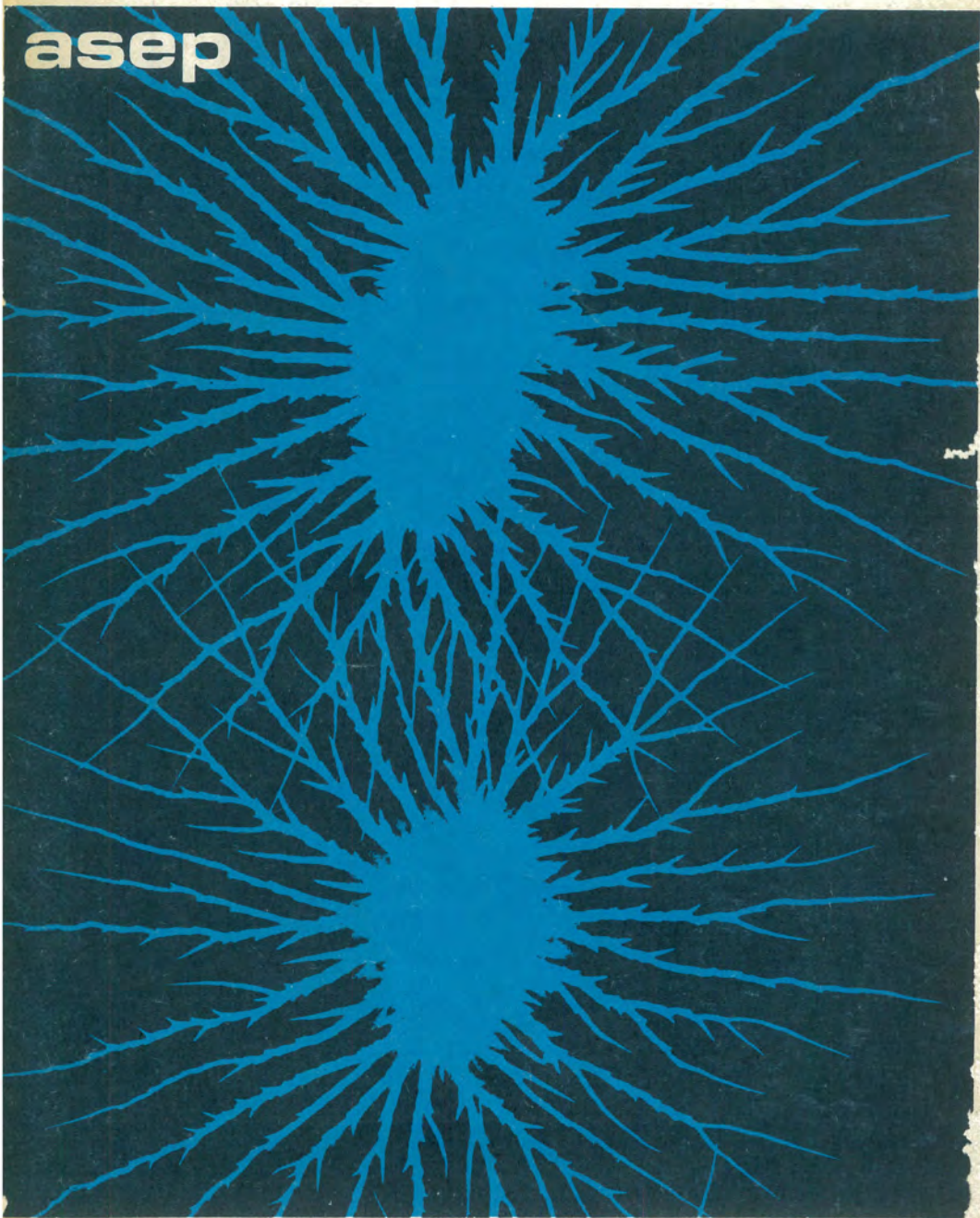
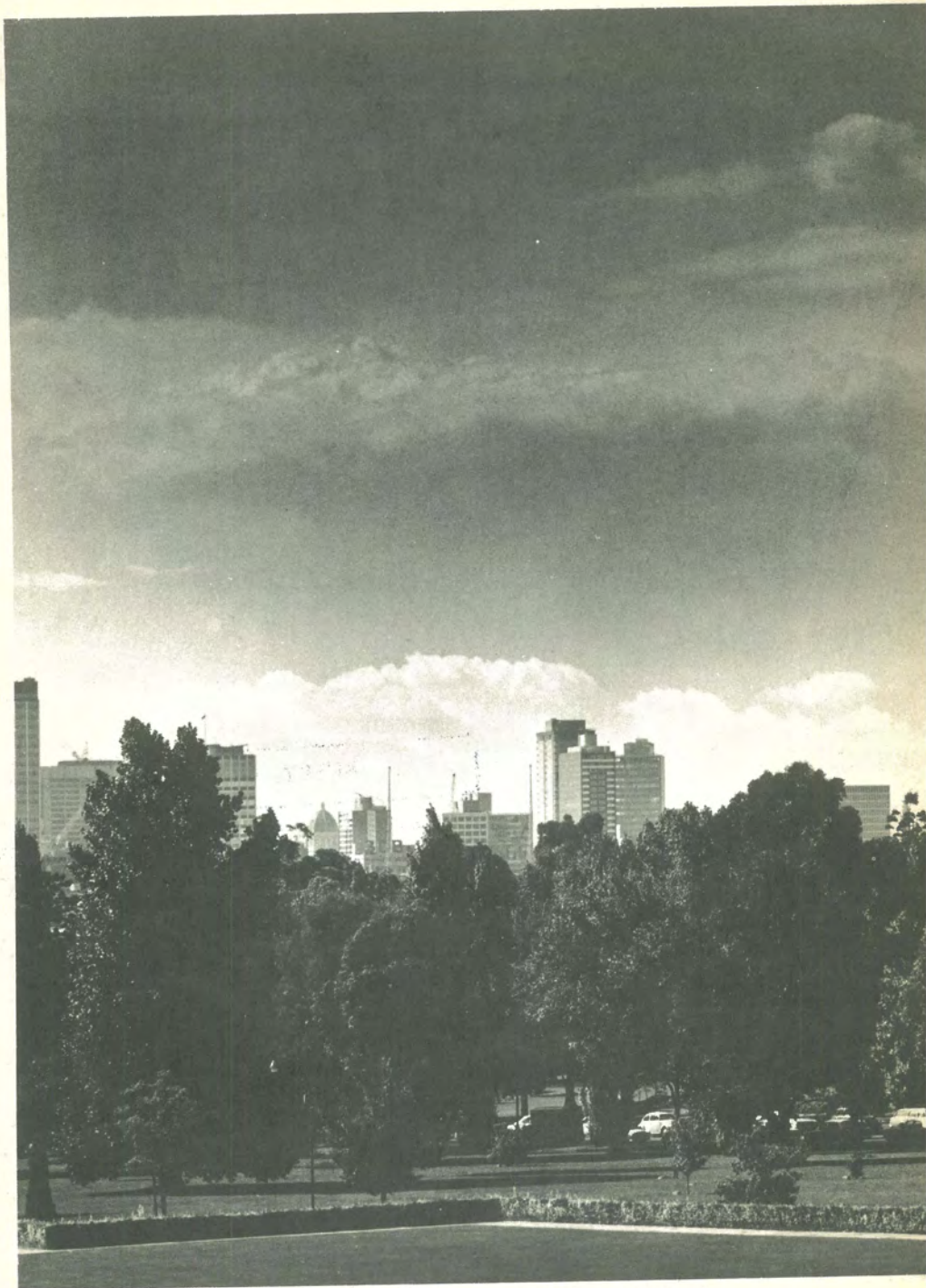


Charge!

asep



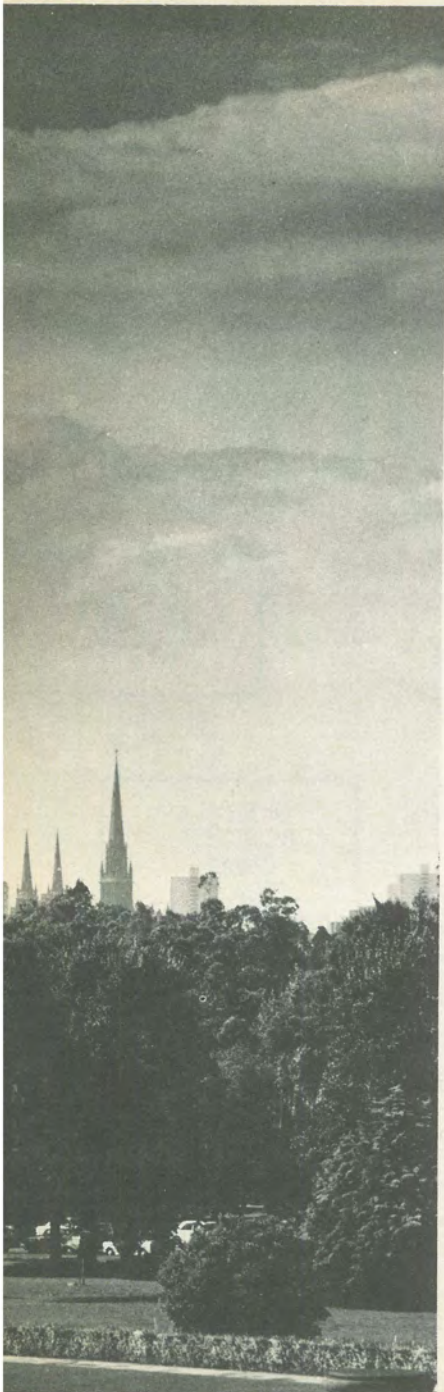
AUSTRALIAN SCIENCE EDUCATION PROJECT



Black clouds invade a blue sky. Soon there will be lightning and thunder.

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It gets darker and darker. Black clouds invade the last bit of blue sky. Suddenly lightning flashes through the clouds. It is exciting, even terrifying.

Our remote ancestors believed that lightning was the spears hurled at them in anger by the mighty gods.

What is lightning? What causes lightning and thunder? Is there a connection between lightning and sparks and crackling noises?

What is electricity? How can electricity be made?

Charge! helps you to find some of the answers to these questions.

BUSBY HIGH SCHOOL		
DATE	NAME	CLASS
30-6-80	Searc Walsh	10 ₅ ₃

(The photograph on the front cover is reproduced by courtesy of Kodak (A'sia) Pty Ltd.)

This book is part of the learning material developed by the Australian Science Education Project (ASEP). The Project was funded by the Commonwealth and State Governments of Australia.

CONTENTS

CHARGING

Page 5

This section introduces you to electric charge. You find out the difference between charged and uncharged objects and notice some of the strange things that can happen when charged objects are around.

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HOW DO
CHARGED OBJECTS
BEHAVE?
Page 26

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WHODUNIT?
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TEST YOURSELF
Page 97

OPTIONS

These can be done
in any order. They
are described in
outline on
pages 24 and 25.

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DEMONSTRATIONS AND DISCUSSIONS

When you see the symbol  you will need to write the answer or information in your notebook. After you answer a question from *Charge!* and when you complete a Test Yourself section refer to the Check Your Answers section. This section starts on page 98. If your answer differs from the one given, go back and recheck your result or reply. If, after this, you cannot agree, discuss your answer with students or with a teacher.

Charging



When you do the activities from *Charge!* it is most important that everything is free from dust and grease. Don't forget your hands. If you leave fingerprints over things you handle, you will probably be very disappointed with the results of your tests. The materials you use should also be dry.



ACTIVITY 1: GETTING TO KNOW CHARGE

You will need:

- 1 plastic strip, about 25 cm x 2 cm
- 1 sheet of dry paper, foolscap size
- 1 balloon
- 1 piece of cotton or string—to tie up the balloon
- 1 piece of cotton material, about 15 cm x 15 cm
- 1 piece of nylon material, about 15 cm x 15 cm
- 1 piece of tissue paper, about 10 cm x 10 cm
- 1 piece of aluminium foil, about 3 cm x 3 cm.
- 1 teaspoonful each of kitchen salt and sugar
- water, running from a tap
- soap solution
- 1 plastic drinking straw.



Sticky paper?

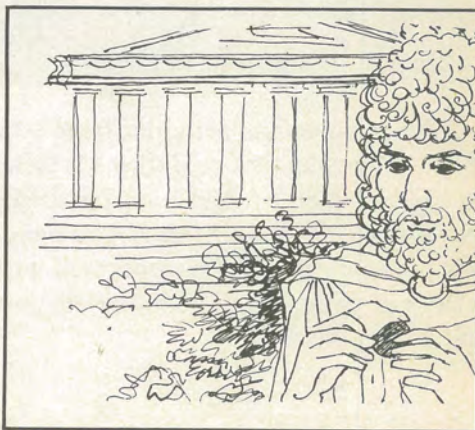
Hold the piece of dry paper against a smooth wall. If you let the paper go it will fall. Try it.

Hold the paper against the wall with one hand and use your other hand to stroke the paper firmly with either of the materials. Stop holding the paper. What happens to it?

Lift one corner of the paper off the wall. Does the paper jump back?

Blow up the balloon. Rub it with either of the materials. Bring the balloon close to somebody else's balloon. What happens?

Rub the plastic strip with the cotton material. To do this, fold the material, fairly tightly, around the





Rubbing a plastic strip with cotton.

strip. Pull the strip through the fold three or four times.

Hold the strip you have been rubbing close to:

- your partner's hair (or the hair on your arms).
- water running in a thin stream from a tap. (If the strip gets wet, dry it and rub it again.)
- soap bubbles.
- small pieces of tissue paper. (Tear about half of the tissue paper into little bits and leave them on the table.)
- salt or sugar sprinkled on the rest of the paper.
- other little things, such as cut-up aluminium foil.



A hair raising event!

You can use the word 'bits' from now on for all the bits of foil, tissue paper, cotton wool, sugar, salt and so on you will be using.

Paper, balloons, plastic strips and many other objects change after rubbing. They do not look any different, but they can do some things that they couldn't do before. Before they were rubbed the objects could not pick up 'bits'; after rubbing they could. Test this for yourself.

You can call your rubbed balloons, plastic strips and so on, **electrically charged** if they can pick up 'bits'. This is not the best test to find out if an object is charged, but it will do until you discover more about charge.

Where the word 'electric' comes from

Thales (*THAR-les*) of Miletus was a Greek who lived more than 2500 years ago. He had a very nice clasp which was made from a brownish-golden material called amber. One day Thales noticed that his clasp was a bit dirty, so he polished it with the folds of his woollen cloak. Did he get it nice and clean? Not at all. Little bits of fluff stuck to it and made it look worse than ever. He had **charged** the amber.

We now use the Greek word for amber, *elektros* for this special charge in materials. We say the materials carry an electric charge.

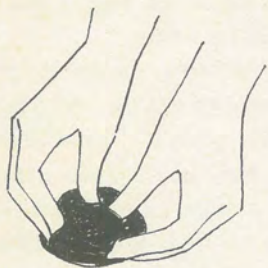
ACTIVITY 2: MAKING A TESTER

You will be able to find out more about charges and charging if you have a tester.

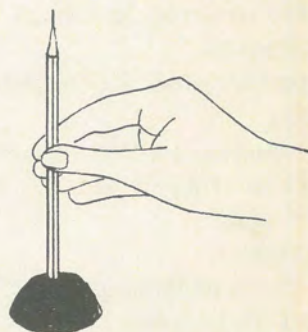
You will need:

- 1 small test-tube
- 1 sharp pencil
- 1 plastic strip, about 10 cm x 1.5 cm, cut from an acetate plastic sheet
- 1 piece of clean cotton material, about 15 cm x 15 cm
- small quantity of plasticine
- some 'bits'.

1 Make a plasticine base.

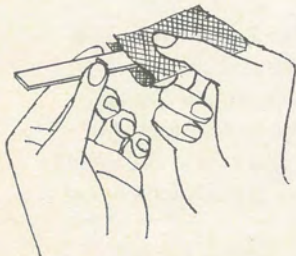


2 Push the unsharpened end of the pencil into the plasticine so that the pencil stands up.



3 Mark the plastic strip with an 'A'. Hold the strip in the middle and charge both ends with the cotton material.

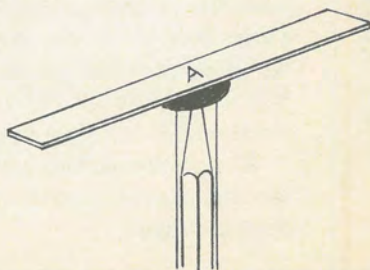
(Always charge your A tester with cotton material.)



Check that the strip is charged.
Does it attract small 'bits'?

4 Put a blob of plasticine on to the closed end of the test-tube and stick the middle of the charged strip to the blob.

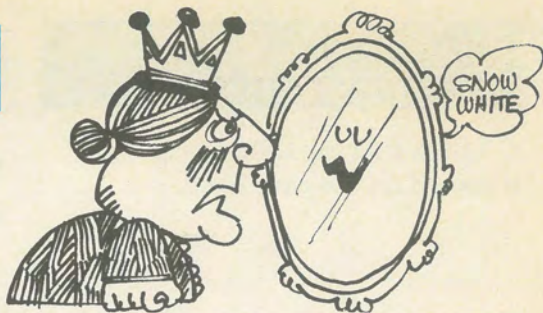
Place the test-tube, with the strip on it, over the pencil and balance it on the sharp pencil point. The tester is now ready for use.



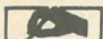
ACTIVITY 3: ARE YOU ATTRACTIVE?

In this activity, you can use the tester to find out how attractive you are.

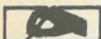
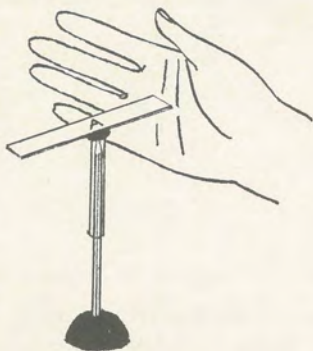
First, check the tester to see if it is still charged. Can it still attract 'bits'?



Hold one of your hands close to one end of the charged tester but don't touch it.



1 What happens to the charged tester?

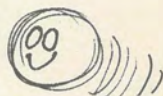


2 Are you charged? Can you attract little 'bits'?

Bring a number of other things such as pencils and scissors near your charged tester. First, make sure that they are not charged by holding them close to 'bits'. If your things are charged, you can **discharge*** them by passing them quickly over a low burner flame.



3 What does the tester do in each case?



From Activity 1 it appears that charged objects attract uncharged ones.

From Activity 3 it appears that uncharged objects attract charged ones.

* Discharge means removing extra charges.

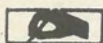
ACTIVITY 4: USING THE TESTER

Check that the tester is charged—it should follow your hand.

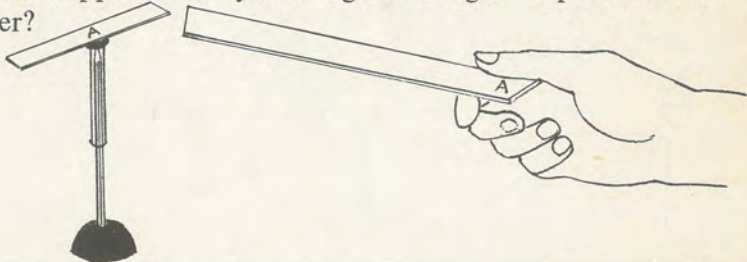
You will need:

- the tester
- some 'bits'
- 1 piece of cotton material, about 15 cm x 15 cm
- 1 piece of nylon material, about 15 cm x 15 cm
- 2 plastic strips, from the class supply. One strip has a corner cut off and you should mark this strip 'A'. Mark the other plastic strip 'B'. Always hold the strips at the marked ends.

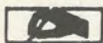
Charge strip A by rubbing it with the cotton material. (The strip will pick up 'bits' when charged.)



4 What happens when you bring the charged strip A close to the charged tester?

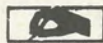


Charge strip B, using the nylon material. Bring the strip close to the charged tester. (You may need to recharge the tester.)



5 What do you notice this time?

Make a B tester by charging the tester strip with nylon instead of cotton material.



6 What happens when you bring charged strips A and B up to the charged B tester?

It looks as though the electric charge on strip A is different from the electric charge on strip B. Many tests, similar to the ones you have just completed, verify this difference.

Strips A and B are made of the same plastic. If you rubbed them both in the same way, the difference could only be due to the different rubbing materials you used:

- Cotton for strip A
- Nylon for strip B.



ATTRACTION AND REPULSION

Using a system suggested by the grandfather of electricity, Benjamin Franklin (1706–90), A-type charge is called **positive** (+) charge and B-type charge is called **negative** (-) charge.

Franklin named the charge on a glass rod rubbed with silk positive (+) charge. A-type charge is the same as this.

In Option 6 (Whodunit?), there is more information on Benjamin Franklin. You may like to read this.

The table at right gives a summary of what you have probably noticed about uncharged objects and objects which are positively (+) or negatively (-) charged.

There is another way of saying it:

- Objects carrying unlike charges attract each other.
- Objects carrying like charges repel each other.
- Objects carrying no charge attract objects which are charged.

POSITIVE +
NEGATIVE -



Charged strip A = positive (+)

Charged strip B = negative (-)

Uncharged strip = ○

— ATTRACTS ○

○ ATTRACTS —

+ REPELS +

— REPELS —

+ ATTRACTS —

— ATTRACTS +

+ ATTRACTS ○

○ ATTRACTS +

A generalization such as 'like charges repel each other' cannot be made after just a few tests. But very many tests similar to the ones you have done have given the same results over many years. Because of these tests we can generalize confidently.

Charged and uncharged materials can be attracted by a charged object. Therefore, the only sure sign that a body is charged is if it repels another charged object.



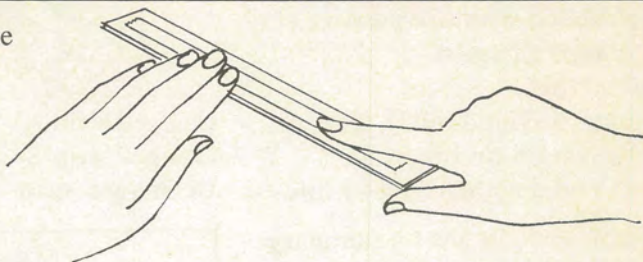
ACTIVITY 5: POSITIVE AND NEGATIVE

Charge the tester as you did before (page 8). Make sure that it does carry electric charge. If not, recharge it.

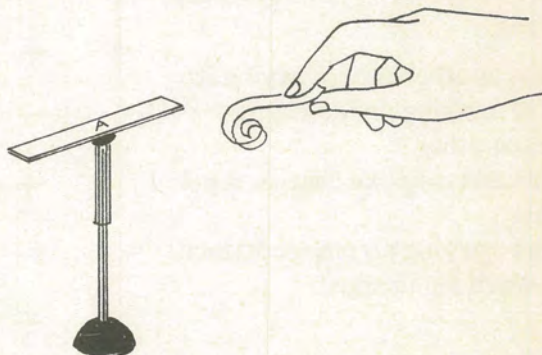
You will need:

- 1 piece of adhesive tape, about 10 cm
- 1 piece of plastic slightly wider and longer than the tape
- everything you used in Activity 4.

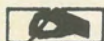
Stick the tape to the piece of plastic.



Pull the tape off quickly and hold it close to the charged tester.



7 What does the tape do to the tester?



8 Bring the plastic close to the tester. Does the tester act the same or differently?

Does a rubbing material become charged at the same time as a strip? If it does, what charge does it carry?



9 Find out for:
☐ your strip A and cotton material.
☐ your strip B and nylon material.



When charging occurs, two types of charges are formed. One type on the charged object, the opposite charge on the rubbing material.

ACTIVITY 6: THE GLOW-LAMP

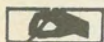
Make a handle for the glow-lamp as shown.

Rub the clean strip A with the clean dry cotton material. You will probably hear crackling sounds while you are rubbing.

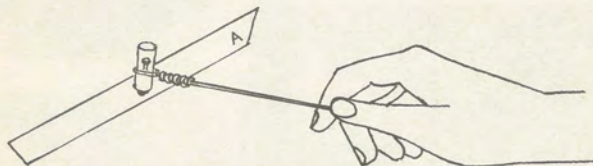
Have the room as dark as possible. Shade your working area if necessary.

You will need:

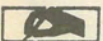
- 1 small neon glow-lamp
- 1 strip A and cotton material
- 1 strip B and nylon material
- 1 length of wire, about 15 cm to 20 cm.



10 Touch strip A with the lamp. What do you see?



11 Try other spots on the strip. What do you notice?



12 Repeat for the strip B and nylon material.

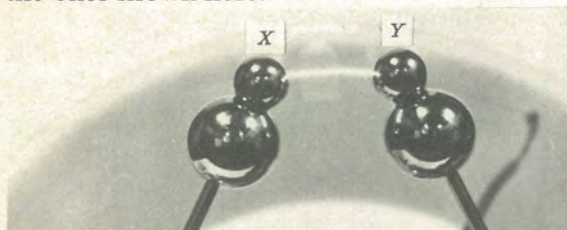
It seems that charges may move from the touch point through to the glow-lamp, causing it to flash.

Charges cannot, however, move from one spot on the plastic to another. If they could, you might expect the lamp to glow for a longer time—not just flash.

What about lightning? How is it formed? Is the flash caused in any way by electric charges? Charge Generators (over the page), looks at this possibility.

CHARGE GENERATORS (PRODUCERS)

You may have seen machines like the ones shown here.

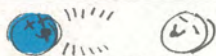


A Wimshurst charge generator generates charge and stores it in sections W and Z. When sufficient charge is stored sparks can jump across the gap XY.



A van de Graaff charge generator generates charge and stores it on the outside of the metal head. When enough charge has been stored, a spark can jump across to a nearby uncharged object.

VAN DE GRAAFF
GENERATOR



A spark can jump when:

- ☐ two highly charged objects with unlike charges are near each other.
- ☐ an uncharged object is close to a highly charged object.

You cannot see charges as they are far too tiny, but you can see what they do.

The charges are attracted so strongly that they are ripped off and fly through the air, as sparks, between the objects. The air becomes hot and expands—and so crackling sounds may be heard.

What Is Lightning?

Lightning is a gigantic spark which is produced when electric charges from within a cloud move suddenly from cloud to cloud or from cloud to earth. Instead of little crackling noises you hear booming thunder.

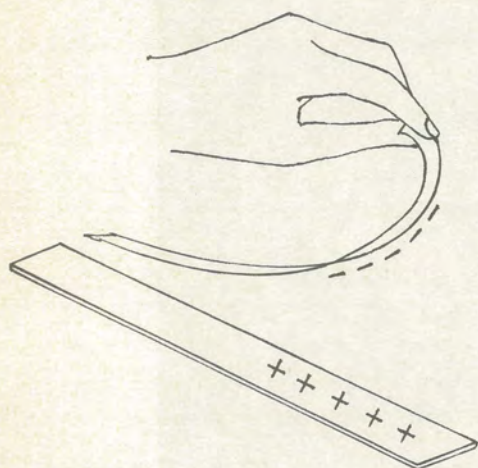
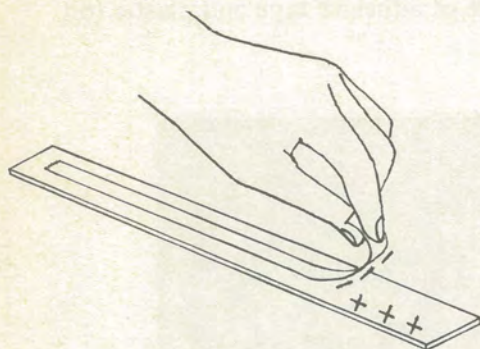
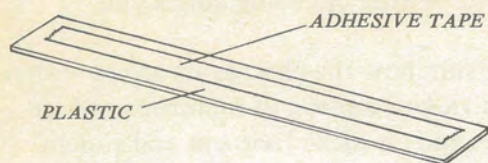
Nobody, as yet, knows for sure how the charges are made within a cloud. They may arise from violent motion of raindrops and ice crystals. Raindrops, hailstones and air make frequent and violent contact with each other. These things can become charged on separation just like your piece of adhesive tape and plastic (on page 12).



A massive charge has built up in the clouds. Now a flash of lightning splits the night sky and thunder booms across the land.

(Photo by courtesy of Richard E. Orville, State University of New York at Albany.)

HOW DOES CHARGING OCCUR?



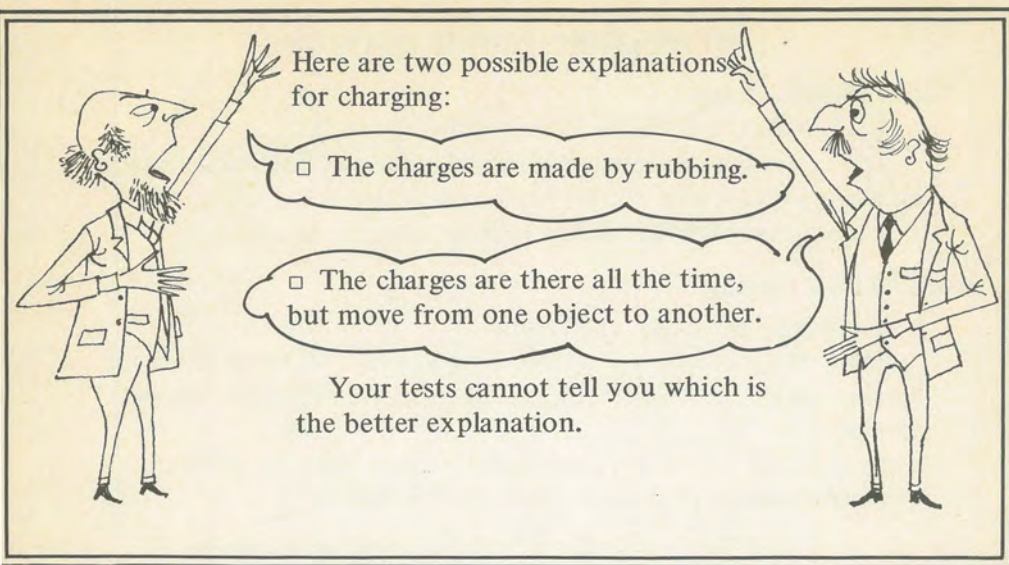
Perhaps you made the charges out of nothing as you stroked the strips, or pulled things apart? Maybe charges can be created by rubbing? After all, you used some force and did some work.

Does uncharged mean that there are no charges? Maybe the charges in the strips and the materials were there before you began rubbing? Perhaps they were in the balloons and the other objects, too?

Why didn't these things pick up 'bits' if they had charges in them?

Is it possible that for every positive charge in a strip, there is also a negative charge? You know from mathematics lessons that plus one added to minus one gives zero. Therefore a plus (positive) charge with an equal minus (negative) charge would show no effect. An uncharged strip would be uncharged because it has an equal number of positive and negative charges.

You brought two different materials together and then separated them. It could be that the plastic gained one kind of charge from the adhesive tape and in return the adhesive tape gained the other kind of charge from the plastic.



Here are two possible explanations
for charging:

□ The charges are made by rubbing.

□ The charges are there all the time,
but move from one object to another.

Your tests cannot tell you which is
the better explanation.

WHAT SCIENTISTS HAVE TO SAY ABOUT CHARGING

Scientists can measure the amount of charge on an object. They do this by measuring how strongly one charged object attracts or repels another one. They always find that there is just as much positive charge on, say, the strip A as there is negative charge on the cotton material used to charge it. The charges are there all the time but move from one object to another.

The second explanation is better because it shows why + charge is always made together with - charge, and why there is always an equal quantity of + charge and - charge.

Experiments confirm the idea that the charges are there all the time and are pulled apart when two materials which are touching each other are separated.



EXPLANATIONS ABOUT CHARGING

What Is Electric Charge?

A scientific model helps to answer this question.

You can make up a scientific model whenever you want to explain something which you cannot explore directly.

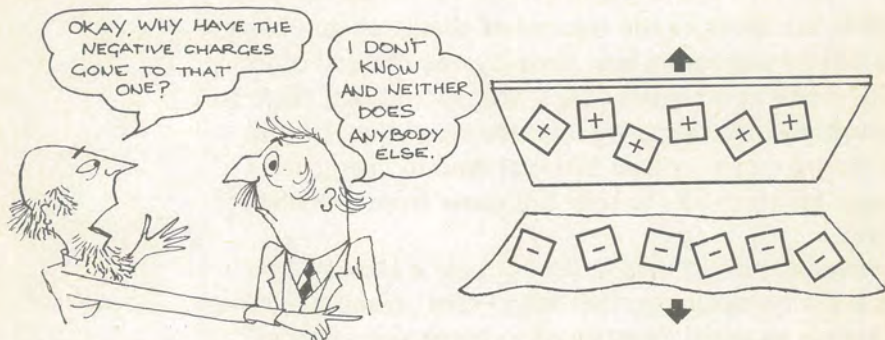
A model uses familiar things to help us clear our ideas.

A Model for Charging

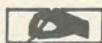
- Everything is usually uncharged.
- Everything is made out of 'building blocks'. All these 'building blocks' are charged. Some 'blocks' are positive and some 'blocks' are negative.
- Most things are usually uncharged because they are made up of equal numbers of positive and negative 'blocks'.

$$\boxed{-} \boxed{-} \boxed{-} + \boxed{+} \boxed{+} \boxed{+} = \boxed{\text{uncharged}}$$

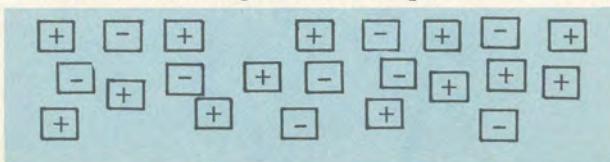
- Charging means separating the 'building blocks', so that the object has an unequal number of positive and negative 'blocks'.



- The charged 'building blocks' are very tiny. (Charges can't be seen.)
- A **positive charge** on a strip (or other object) means more tiny positive 'blocks' (charges) than negative ones on the strip.
- A **negative charge** on a strip (or other object) means more negative 'blocks' (charges) than positive ones.



13 What is the charge on this strip?

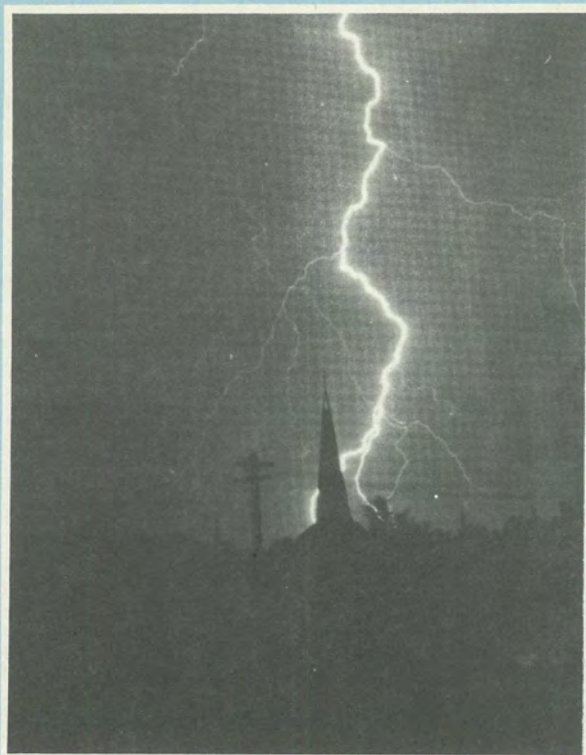


TEST YOURSELF—CHARGING

This test, and the tests at the end of each option, are to help you find out if you understand what you have been doing. It is important that all your answers are your own work. It is not a test for marks.

For most questions, you have to choose the best answer from the several answers suggested. In each of these cases, write only the letter of the answer which you choose. Answer the following questions on a page of your notebook.

1



(Photo by courtesy of the News, Canberra.)

Which one of the following does **not** describe what happens during the course of a thunderstorm?

- A Electric charges are separated by weather conditions.
- B Strong winds and updraughts knock particles in the clouds against each other.
- C The vibration of the thunder causes a giant spark to jump from cloud to cloud or from cloud to Earth.
- D Electric charges build up in different areas in the clouds.

Test Yourself continued next page

Questions 2 to 4 refer to the diagrams of two balloons.

2

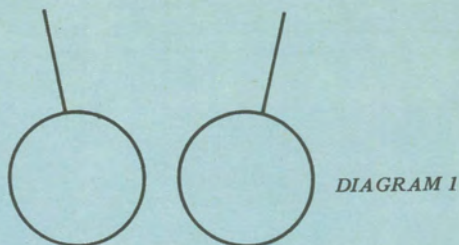


Diagram 1 shows the two balloons attracting each other. Which of the following statements (**one or more**) could explain this attraction?

- A One balloon is charged and the other balloon is uncharged.
- B Both balloons are charged, and carry like charges.
- C Both balloons are charged, and carry unlike charges.
- D Both balloons are uncharged.

3

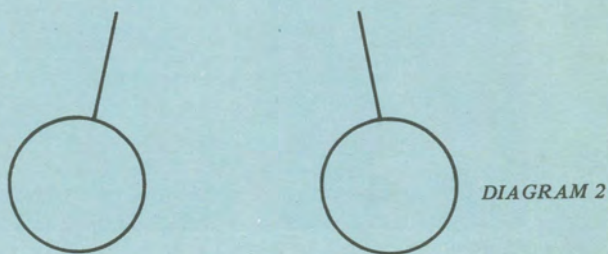


Diagram 2 shows the two balloons in different circumstances. They are now repelling each other. Which of the following statements (**one or more**) could explain this repulsion?

- A One balloon is charged and the other balloon is uncharged.
- B Both balloons are charged, and carry like charges.
- C Both balloons are charged, and carry unlike charges.
- D Both balloons are uncharged.

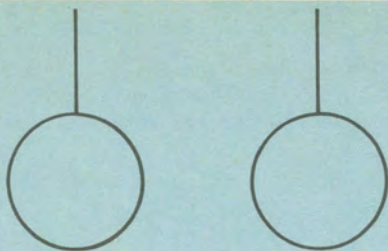
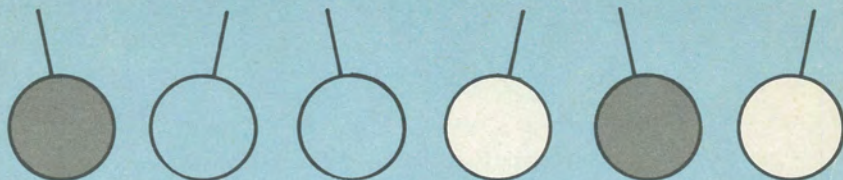


DIAGRAM 3

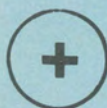
Diagram 3 shows the two balloons in yet another set of circumstances. Now they appear to be neither attracting nor repelling each other. Which of the following statements (**one or more**) could explain why there is now no apparent attraction or repulsion?

- A One balloon is charged and the other balloon is uncharged.
 - B Both balloons are charged, and carry like charges.
 - C Both balloons are charged, and carry unlike charges.
 - D Both balloons are uncharged.
-
- 5 Carmen stuck a piece of adhesive tape on a plastic strip. Then she pulled the tape off quickly. She tested the tape and the strip to see if they were charged. Of the following, which **one** would have been the most likely result?
- A The tape was charged and the strip was uncharged.
 - B The tape was uncharged and the strip was charged.
 - C Both the tape and the strip were charged, and carried like charges.
 - D Both the tape and the strip were charged, and carried unlike charges.
- 6 A boy rubs a plastic strip on his woollen jumper and the strip becomes negatively charged. When he rubs it on his drip-dry shirt the plastic strip will
- A become positively charged.
 - B become negatively charged.
 - C be uncharged.
 - D become positively or negatively charged, depending on the material of his drip-dry shirt.

- 7 A teacher displayed three coloured balloons. One balloon was grey, one was blue, and the other was white. When any two of these balloons were hung close together, they attracted each other, as shown in the diagrams below.



Which set of diagrams below could explain the attraction between the coloured balloons?



indicates a balloon which is positively charged



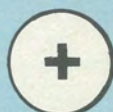
indicates a balloon which is negatively charged



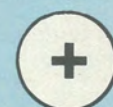
indicates a balloon which is uncharged

Hint: Go through each of the suggested answers below in turn and see whether the balloons of each pair would attract each other.

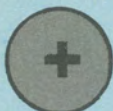
A



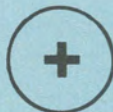
B



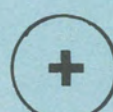
C



D



E



- 8 A positively charged object contains
- A positive charges only.
 - B an equal number of positive and negative charges.
 - C more positive charges than negative charges.
 - D more negative charges than positive charges.

If you have left out pages 16 to 18, you need not attempt questions 9 and 10.

- 9 When a glass rod is rubbed with silk, the glass rod becomes positively charged while the silk becomes negatively charged. The positive charge on the glass is
- A greater than the negative charge on the silk.
 - B equal to the negative charge on the silk.
 - C less than the negative charge on the silk.
- 10 Which **one** of the following statements about scientific models is **not** true?
- A By using models, scientists are able to give true descriptions of nature.
 - B There may be several different models used to try to explain the same thing.
 - C Models may be changed as more evidence is gathered.
 - D Models use familiar things to help us understand unfamiliar ideas.

Now turn to Check Your Answers on page 99.

OPTIONS

You can choose among the options and you can do them in any order you like. However, it would be better to do either Option 2 or Option 3 before doing Option 5.

When you decide to do a particular option, get together with other students who want to do it, and consult with a teacher.

Once you have started an option, you should try to complete it.



OPTION 1: HOW DO CHARGED OBJECTS BEHAVE? Page 26

You find out more about charges in a room and in industry. And about charges being a help and charges being a nuisance.



OPTION 2: WHAT IS BLUE? Page 42

You find out about charges in liquids and in crystals. This option will appeal to you if you like puzzles.



OPTION 3: PUTTING ON A SHINY COAT Page 54

You find out how some 'silver' spoons are made and how bumper bars of cars are chromium plated.



OPTION 4:
ELECTRIC CELLS Page 64

You make your own electric cell to light up a torch globe. You also find out what is inside a transistor radio battery.



OPTION 5:
WILL ANY LIQUID DO? . . Page 73

You get a further look at electricity and find out if all liquids conduct electric current.



OPTION 6:
WHODUNIT? Page 82

This is mainly reading about three pioneers in electricity—Franklin, Galvani, and Volta.

Your notebook should contain details of everything that you have done in each of the options you choose. When you answer questions from the options be sure to put the question number alongside your answer.

Remember, your notebook is the only record of what you have done. You may need to refer to it at a later stage to write reports or check on details of an investigation.

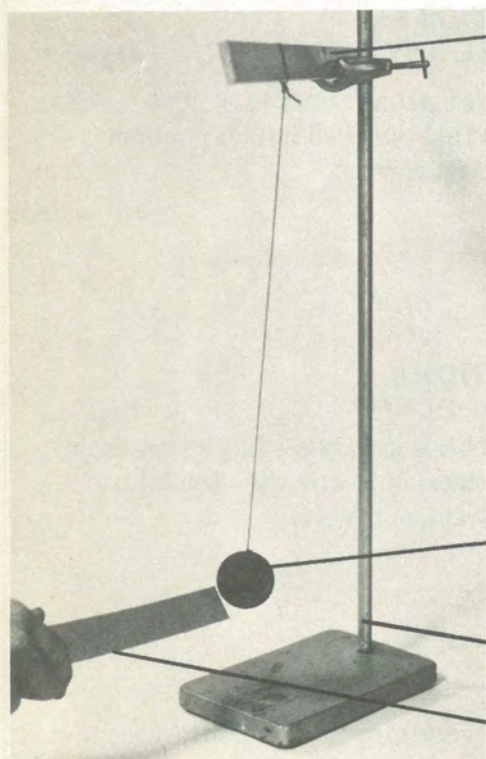
OPTION



At the end of this option you will probably be able to:

- ☐ Use the terms 'conductor' and 'insulator'.
- ☐ Suggest more tests to find out whether an object is charged, and the kind of charge it carries.
- ☐ Test whether a substance is a good or a poor conductor of electric charges.
- ☐ Explain many things in terms of charges.

How Do Charged Objects Behave?



RULER

POLY
BEING
ATTRACTED

STAND

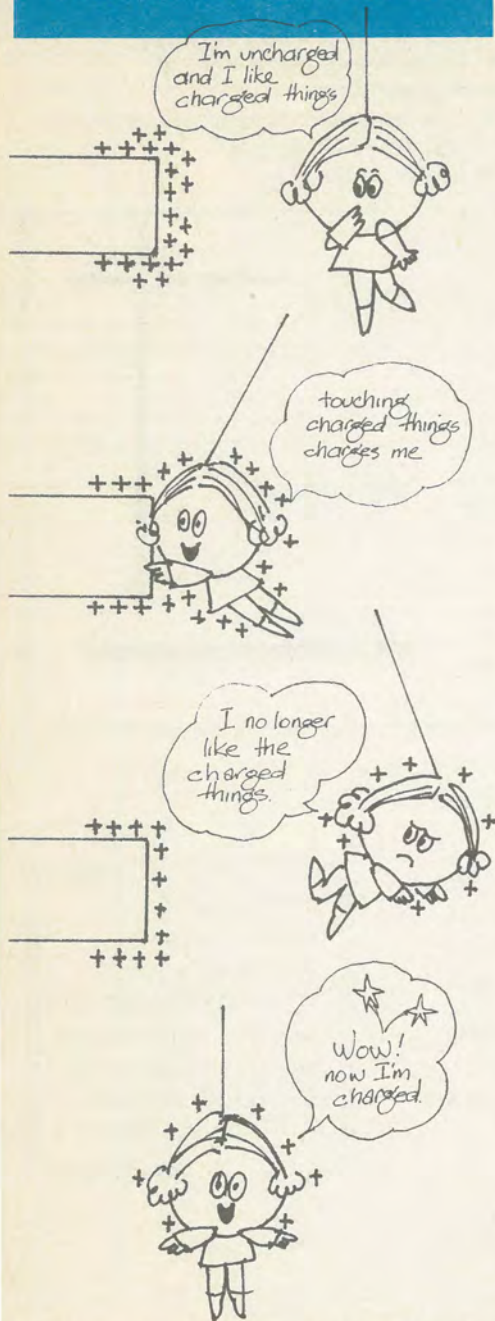
STRIP

In this option you make a different kind of tester to give you a chance to find out more about the ways in which charged objects behave.

You could work together with partners. You then become part of a team and can compare and discuss results.

Setting up a Poly tester.

ACTIVITY 1: POLY TESTER



To make the different tester you will need:

1

- 1 little ball made of Polystyrene foam.
You can call the ball 'Poly' for short. Poly has been painted with black graphite* and has a nylon thread attached.
- 1 ruler
- 1 clamp and stand
- 1 strip A
- 1 piece of cotton material.

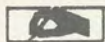
Clamp the ruler horizontally as in the photo on the opposite page.

Fix Poly's nylon thread to the ruler so that Poly can swing freely.



1.1 Charge a strip A and bring it close to Poly until they touch, however briefly. Lots of things will happen. Describe them as well as you can in your notebook.

Take the strip away.



1.2 Bring the charged strip close to Poly again, about 2 centimetres to 3 centimetres away.

What happens now?

What kind of charge is on Poly?

Remember that:

- ☐ like charges repel,
- ☐ unlike charges attract, and
- ☐ uncharged things attract and are attracted by charged ones.

This charging is quite different from the charging which you did before (page 6). How did this different charging come about? You could begin by talking it over with a partner.

Poly must have become charged as it was repelled by the strip but it became charged without stroking. To find out about this you can do Activity 2.

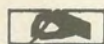
*Graphite is one of the materials of which the lead in pencils is made. *Graphos* is a Greek word which means 'to write'.

ACTIVITY 2: POLY AND CHARGES

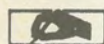
You will need:

- 1 beaker or glass jar, clean and dry
- 1 metal rod or cylinder, about 15 cm long (a pair of scissors will do)
- 1 strip A and cotton material
- Poly and stand
- 1 uncharged plastic strip also clean and dry, about 18 cm long
- 1 carbon rod.

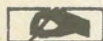
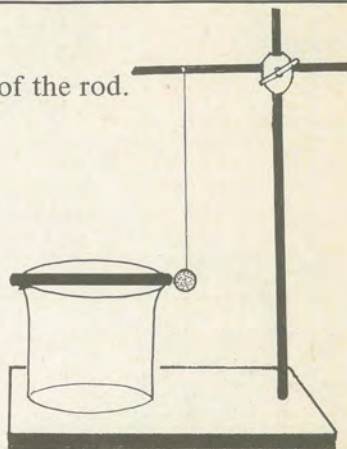
- 1 Put the metal rod on top of the beaker.
- 2 Set up Poly. Have it just touching one end of the rod.
- 3 Touch the other end of the rod with the charged strip A.



1.3 What happens?



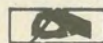
1.4 How did charges get to Poly?



1.5 Repeat steps 1 to 3, but use the uncharged plastic strip instead of the metal rod. What happens?

Charges from the charged strip A were able to move along the metal to Poly giving Poly a charge. The metal conducted the charges.

Charges were not conducted by the plastic.



1.6 Now try other substances instead of the metal or the plastic. (You could try a carbon rod, a lead pencil, a piece of paper or an uncharged plastic strip.)

Make two lists. Make one list of the things which conducted charges to Poly. Then make another list of the things which did not conduct charges.

Discuss your lists with your partner and with others who have done the same activity.

Substances which allow charges to move easily are called **conductors**. The other substances are called **insulators**. Insulators seem to hold charges firmly.

Now you should be able to understand how Poly became charged in Activity 1.

The surface of Poly is coated with graphite which is a form of carbon. On page 28 you probably found that carbon is a conductor. So Poly is a conductor and can take over charges from the charged strip A.

This form of charging is called **charging by conduction**.

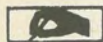
The nylon thread supporting Poly is an insulator so charges can't move to it from Poly.

Poly was charged with the same kind of charge as the strip A. You know this because it was repelled by the strip (like charges repel). Poly must have received some charges from the charged strip A.

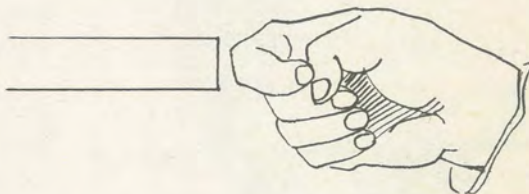
More About Conductors

Is air a conductor? Can charges move through air?

Hold the palm of your hand and then the knuckle of your index finger near a charged strip.



1.7 What do you notice?

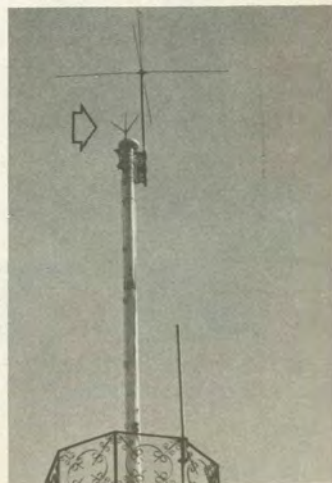


Air can be a conductor. Charges can move in air, but they have to work hard to do that. The air gets very hot—so hot that you can see sparks and hear crackling noises.

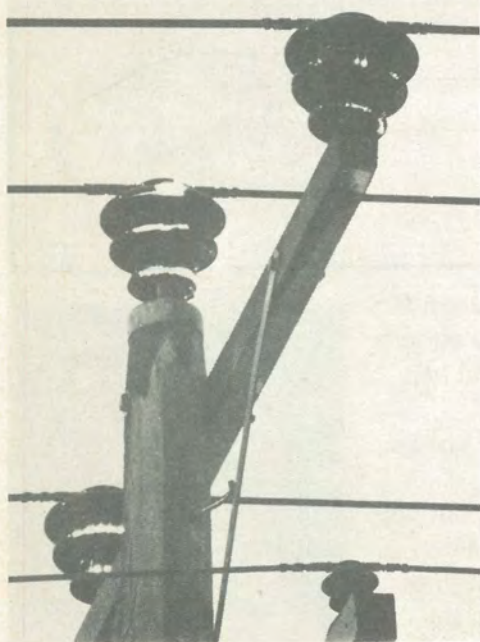
This is what you saw and heard with the charge generators on page 14.

Lightning is a gigantic spark that causes thunder (see page 15). Lightning strikes pointed objects more often than rounded ones. This is what you would expect from what you have found in the above investigation.

A three-pronged lightning conductor. Would the recently added aerial affect the job done by the lightning conductor?



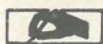
ACTIVITY 3: DO INSULATING MATERIALS ALWAYS REMAIN INSULATORS?



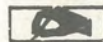
Transmission lines insulated from support pole by ceramic insulators.

You will need:

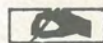
- 1 beaker or glass jar, clean and dry
- Poly and stand
- 2 narrow strips of plastic, 2 pieces cut from an acetate sheet will do
- 1 strip A and cotton material
- a small quantity of oil.



1.8 Take one narrow strip of clean, dry plastic. Does it conduct the charge from the charged strip A to Poly?



1.9 Moisten the strip all over with water. Does it carry charge for Poly now?



1.10 Take the other narrow plastic strip and make it greasy with a drop of oil. Does the oily strip conduct charge to Poly?

Usually, dirty or wet insulators can conduct quite well. It is these extra things on them which can conduct charges.

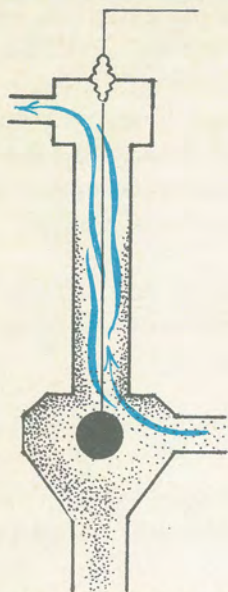
Now you know why it is so important to have everything clean. Otherwise you work hard to get charges separated only to have them run out through your fingers.

An insulator is really a poor conductor. It has a high **resistance** (prevents charge from moving). There is more about this in ASEP's *Electric Circuits*.

You may like to find the answers to these two questions.

- ☐ Can conductors remove the extra charges from a charged Poly?
- ☐ Are you a conductor?

ACTIVITY 4: READING ABOUT CHARGE



Charges can be used to take soot particles out of black smoke.



Printing plates being prepared in a copying machine.

1 Chimneys and Black Smoke

Have you seen chimneys spewing out black smoke and polluting the air? Now, at least the soot in the black smoke can be reduced by using electric charges.

In one method, see diagram opposite, dust and smoke particles pass close to a highly charged wire. The particles pick up charges from the wire, are repelled and collect on the walls of the chimney.

Periodic rapping of the wall shakes the particles into a collecting hopper from which they can be removed.

2 The Print You Read

Books can be printed by a process which involves electric charges being 'sprayed' on to a sheet of paper. Light in a copying machine then removes some of these charges. Particles become attracted to the remaining charged spots and form the print and pictures.

Trace some writing on an acetate sheet with the flat part of a finger nail. Sprinkle chalk dust or powder over the writing. Shake the dust off.

Powder replaces printing ink and electric charges make the powder stick in the desired places.

Activity 4 continued next page



Atomizer gun shoots small charged drops of paint.

At a large city hotel, guests are receiving a rude jolt—an electric handshake—every time they open a door or flick on a switch.

Metal call buttons outside the lifts are “live” and a stenographer told one guest she was scared of her typewriter.

“It’s just like getting a proper electric shock from a faulty appliance. It really hurts.”

The hotel electrician said,

“They put in a new synthetic carpet a few weeks ago and this generates electricity when you walk on it.

“Then, as soon as you touch anything metallic you can get a real zonk”.

The manager stated—

“This often happens with new synthetic carpets. The effect usually wears off fairly soon,” he said.

3 Spray Painting

What do you think of the method at left of spray painting metal surfaces with charged paint particles which are attracted to the uncharged metal? The uncharged metal is ‘earthed’ by being connected by a conducting material to the ground. Charges on the paint particles do not build up on the metal object. It remains uncharged.

If you did not do it earlier, try to attract droplets of water to a charged strip.

4 Sparks

Electric charges can help us in many other ways, but they can also be a nuisance.

The extract at left from an article written by David Jenkins for *The Herald*, (Melbourne) 24 June 1972, is a good example of this. All names mentioned in the article have been removed.

In industry such sparks can cause explosions in certain vapours. Many workers wear special shoes which have a metallic thread embedded in the soles, so that charges can be conducted away harmlessly.

Petrol tanker operators have to be particularly careful about flammable petrol catching fire from sparks. Liquid passing through the nozzle becomes charged and sparks could form unless precautions are taken.

Can you find out what is done to prevent fire or explosion in petrol vapour?



5 Naughty Nylon

Often a lot of money has to be spent to get rid of the unwanted charges which form on many materials. Some people call these charges an 'industrial pest'. Nylon and many other man-made fibres are 'charge prone'. Because they are insulators, any charge on them stays put.

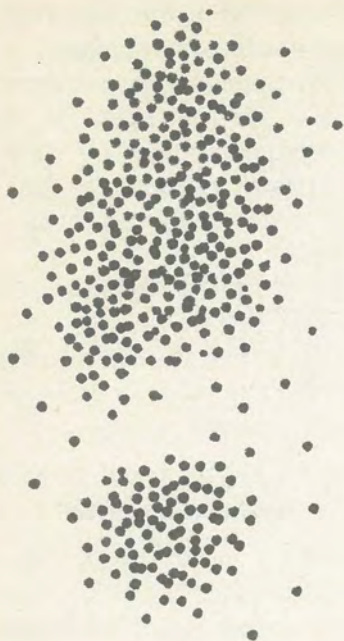
Think of the way nylon shirts and blouses can behave when you take them off. You can see what troubles nylon can cause when it is charged and has to be folded.

- 1 Hang up a nylon tassel. (You can make one from nylon thread.)
- 2 Stroke the tassel with plastic, or with another piece of nylon, or even with aluminium foil. What happens?
- 3 Bring charged strips near to the tassel.

You can imagine what it would be like to try to spin fine threads of nylon together. The fibres repel each other and refuse to be twisted into yarn.

Untreated charged nylon will also attract dust particles ('bits') and become dirty while lying on a shelf.

Special chemicals (anti-stats) have been invented to make the fibres conduct so that the charges can run away. If the air is kept damp the moisture clinging to the surface of the fibres will conduct the charges.



This article first appeared in the New Scientist, 12-10-72, the weekly international review of science and technology. 128 Long Acre, London.

6 Keeping Track of Criminal Feet

Footprints from carpets and floor coverings may soon be an additional hazard for burglars.

A research team at the Shirley Institute in Manchester, England, is using the static charges generated by contact between shoes and carpets to reveal the outline and some of the distinguishing marks of shoe soles.

The pattern of the static charge is normally invisible, but small plastic beads (about 5 mm in diameter) spread over the carpet surface will congregate where the charge is greatest.

The technique was accidentally discovered by Shirley's Dr Kurt Greenwood, who was investigating how efficiently static in carpets could be reduced. Nylon and acrylic based carpets and plastic or vinyl tiles will pick up a pattern of charge in a dry atmosphere. Carpet manufacturers normally limit static by incorporating into the weave a small percentage either of conducting fibres or of fibres specially designed to keep the carpet moist.

Under ideal conditions, a static footprint can last several days. The police department of the Home Office has now contracted the Shirley Institute to develop the technique into a routine police tool. In experiments so far Greenwood and a colleague, Norman Wilson, have successfully reproduced the whirl and line patterns of new shoes, and the wear marks of old shoes.

Floor static will be a feature of buildings for many years to come, says Greenwood. Perhaps break-in kits will soon include a bottle of antistatic fluid?



Sparks that snapped themselves.
(Courtesy Kodak (A'sia) Pty Ltd.)



In cold, dry conditions car bodies can become charged and people stepping out can get an electric shock.

7 Photography

Electric charges can be an expensive nuisance in the manufacture of photographic film. The film material is similar to the plastic strips you have used so far.

As a film moves over rollers it can become charged. On discharging, marks may appear on the film.

The photo at left shows a spark which has taken its own photo on photographic film. (Now you know what the photo on the cover of this book shows—sparks ‘snapping’ themselves.)

One way to prevent charging is to wrap the rollers in moist fabric which has been soaked in a special antistatic solution.

8 The Car-sickness Straps

Some cars have conducting straps dangling to remove the charge which comes from tyres rolling on the road.

In cold, dry air the straps are useful. A car body becomes charged and people stepping out of the car could get an electric shock.

Some people believe they do not get car-sick if there is such a strap on their cars.

Can you suggest a method to find out whether or not this is true?

Synthetics and Charge

Today the use of new synthetic materials has made a big new problem for industry. Large research laboratories are busy everywhere trying to find methods of coping with this problem—the problem of synthetic materials and electric charge.

EXTRA ACTIVITIES YOU COULD DO

Build an Electrophorus

This can be done at home if you wish.

This word 'electrophorus' is made up from two Greek words. You know electro, and phorus means bringing or carrying. So the name tells you what we hope that the electrophorus will do—carry electric charges.

You will need:

- 1 sheet of firm plastic, about 20 cm x 20 cm, clean and dry
- 1 flat, unpainted, metal disc about 10 cm to 15 cm in diameter—but smaller than the plastic sheet. (A flat lid or a pie plate will do, but the edges must be smooth.)
- 1 candle (or a glass rod or a plastic rod) to act as a handle. (The handle must be made of an insulating material.)
- 1 piece of cotton material
- 1 piece of aluminium foil
- plasticine.

- 1 Fix the handle to the metal disc, using candle wax or plasticine or adhesive.



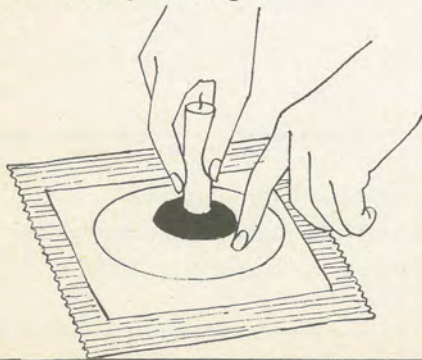
- 2 Place the aluminium foil on a flat surface and lay the sheet of plastic over it.

- 3 Rub the plastic firmly with the cotton material.



- 4 Holding the disc by the handle, place it on the plastic sheet. Just touch the disc with your finger.

- 5 Remove your finger.



- 6 Lift the disc off the plastic by using the handle. **Don't** touch the disc anywhere.

- 7 Your electrophorus should now be charged. Hold it close to your ear. You will probably hear and feel weak sparks.

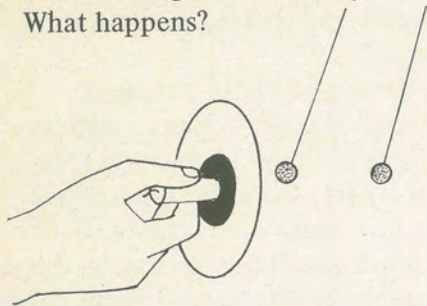


Some suggestions for tests with your electrophorus

1

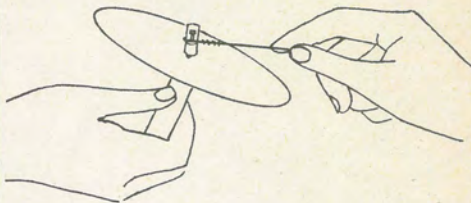
1 You can set up two Polys hanging next to each other and charge them with the electrophorus. Keep putting more and more charge on each Poly.

What happens?



2 Test your charged electrophorus with a glow-lamp, like you did the charged plastic strip (page 13).

What differences do you notice?



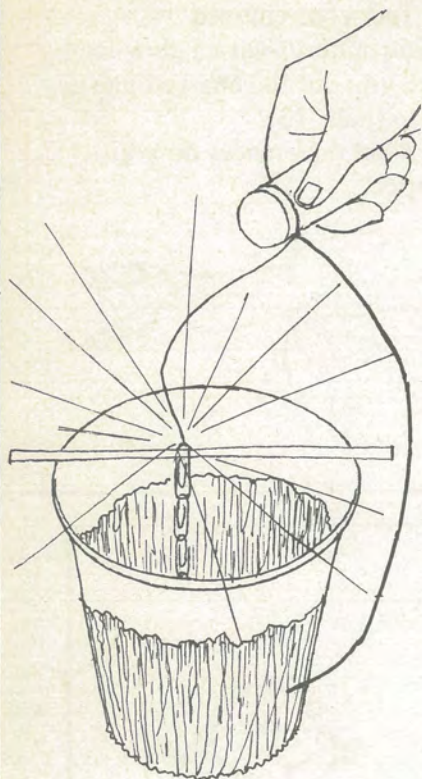
3 You may want to design your own tests to find answers to the following questions.

- ☐ Do charged objects have to touch each other before a pull or push becomes noticeable?
- ☐ Does the distance between the charged objects affect the force between them?
- ☐ If the distance affects the force, does it get bigger or smaller as the objects get closer together?



Extra Activities You Could Do continued next page

Make a Leyden Jar



Wrap aluminium foil on the inside and outside of a plastic beaker until it is about three-quarters of the way up the beaker. Press the foil tightly against the bottom and sides.

Make a chain out of about 10 paper-clips. Slip a strip of plastic through a clip at one end, and allow the bottom clip to rest on the inside foil.

Touch the top clip with a charged electrophorus—the electrophorus will now be discharged and the Leyden jar will be charged. Recharge the electrophorus and repeat the procedure several times. In this way you put a quantity of charge on the jar.

Wind a piece of wire around an insulating handle as shown in the diagram. Touch the foil on the outside of the beaker with one end of the wire and bring the other end close to the top paper-clip. This should draw a spark from the top clip.

The Wimshurst charge generator shown on page 14 uses Leyden jars for storing charge. You could find more information on Leyden jars and other charge storers in many text books.

TEST YOURSELF—HOW DO CHARGED OBJECTS BEHAVE?

1

Answer the following questions in your notebook.

- 1 Which one of the following is the worst electrical conductor?

- A A clean plastic strip
- B A dirty plastic strip
- C A pair of metal scissors
- D A person's finger

Questions 2 and 3

Photo 1 shows an instrument which has a plate (P), a rod (R) and a 'leaf' (L). When the plate (P) is touched with the charged plastic strip (S), the 'leaf' (L) moves away from the rod (R) as shown in photo 2 below.

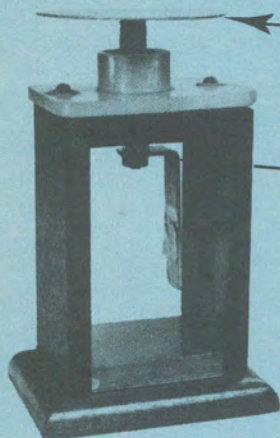


PHOTO 1

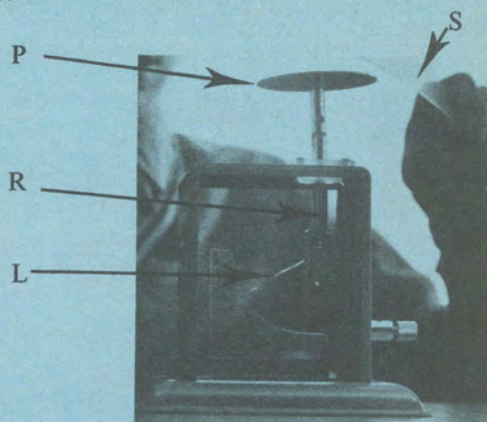


PHOTO 2

- 2 For this instrument to work best, which of P, R and L should be good conductors of electricity?
- A P, R and L
 - B P and R only
 - C R and L only
 - D P and L only
- 3 Which one of the statements below could explain the position of L in photo 2?
- A R and L are both charged and carry like charges.
 - B R and L are both charged and carry unlike charges.
 - C R and L are both uncharged.
 - D R is charged but L is not.
 - E L is charged but R is not.

Test Yourself continued next page

4 **STATIC HAS
HIM ON
THE MOVE**

Special shoes prevent electricity build-up

John Dalton doesn't make any wild claims for his patent boots. They won't support sagging arches or cure bunions.

All they are really good for is helping your hay-fever, keeping your shirts cleaner, and preventing industrial accidents, he says.

Mr. Dalton — a 39-year-old former shoe salesman who lives at Murrumbidgee — has designed a shoe he says stops static electricity building up in your body.

The Age, Melbourne, 26.5.71.

Which one of the following could explain why the special shoes in the report above prevent static electricity building up?

- A The shoes contain a small battery.
 - B The shoes have metal strips built in and these touch the ground.
 - C The soles of the shoes are made of a special new material that is a good insulator.
 - D During manufacture the shoes are given a charge opposite to the charge which builds up in your body.
- 5 Dust collecting in the grooves of an LP record will spoil the sound. If you wipe the surface with a clean cloth, you may well find that afterward the record gets dustier than it would have if you hadn't used the cloth. How can this be explained?
- 6 People walking on nylon carpets sometimes find that a spark jumps from their hands to a metal door handle. Which one of the following does **not** help to explain why this happens?
- A Shoes become charged by rubbing against the carpet.
 - B People have a store of 'animal electricity' in them.
 - C The human body conducts electric charge.
 - D A spark can occur when a charged object is brought near an uncharged object.
- 7 Which one of the following is **not** an example of a method used to prevent or get rid of unwanted electric charge?
- A Some cars have a conducting strap which hangs down and touches the ground.
 - B On the Sydney Harbour Bridge, cars used to touch a wire poking up from the road before reaching the person who collected the toll money.
 - C In factories where nylon is made, special chemicals are sprayed on the nylon before it is wound on reels.
 - D The bodies of modern motor cars are often spray-painted.

Questions 8 to 12

1

The photos below show a small polystyrene ball P suspended from a nylon thread. A plastic strip S is held close to the ball.

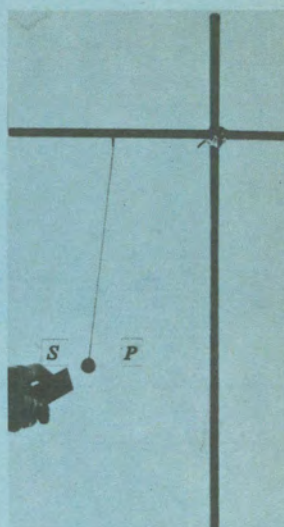
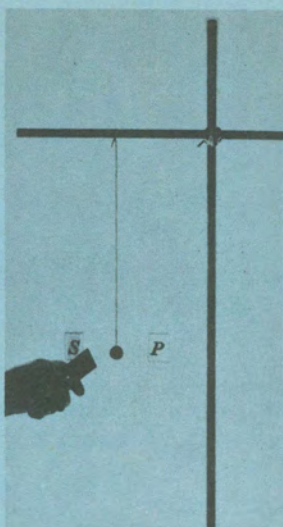
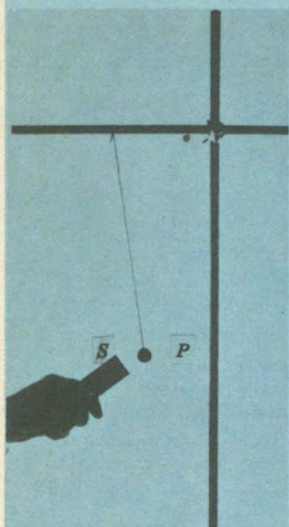


PHOTO 1

PHOTO 2

PHOTO 3

- 8 Which photo could be showing the situation where S and P both carry a positive charge?
- 9 Which photo could be showing the situation where S and P both carry a negative charge?
- 10 Which photo could be showing the situation where S carries no charge and P carries a negative charge?
- 11 Which photo could be showing the situation where S and P both carry no charge?
- 12 Which photo could be showing the situation where S carries a positive charge and P carries a negative charge?

Now turn to Check Your Answers on page 100.

OPTION



Before you do this option you may need to do the test on page 110.

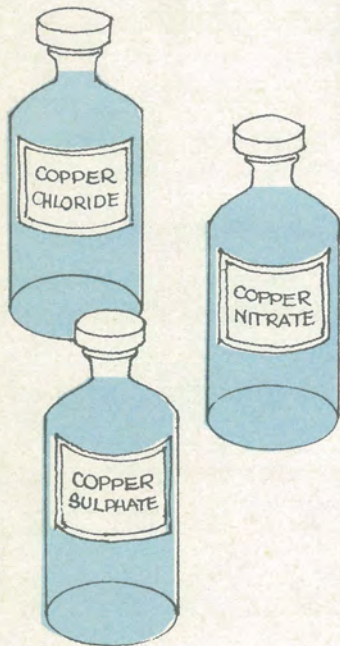
At the end of this option you will probably be able to:

- ☐ Use the terms 'battery', 'terminal', 'atom', 'ion' and 'compound'.
- ☐ Tell the difference between copper atoms (metal) and copper ions.
- ☐ Suggest tests to find out whether currents play a part in converting (changing) atoms to ions and ions to atoms.

What Is Blue?

This option will involve you in a lot of thinking and discussing but not as much 'doing' as the other options.

Look at the bottles provided for this option. Each will have a label with copper something on it (copper sulphate, copper chloride, copper nitrate). The different liquids will all be about the same shade of light blue. This colour could have something to do with the copper or the water or both. It is this colour that you are trying to find out about in this option.



COMPOUNDS

We call a chemical substance which is formed from more than one simple substance (element) a **compound**. Copper sulphate for example is a compound. You can often guess which substances are compounds by looking at their double chemical names. For example, iron sulphate is probably a compound. This simple way will not always work. For instance, have you used alum for growing crystals? Is it a compound? Chemists call it potassium aluminium sulphate. Surely this chemical name tells you that alum must be a compound? But is water a compound?



2



A poisonous brown gas is released when nitric acid reacts with copper. Here a teacher safely demonstrates the reaction inside a fume cupboard.

Ask a teacher to show you what a compound called nitric acid can do to copper metal.

 2.1 See if you can observe more changes than anybody else. Write these changes in your notebook.

In this demonstration you see that:

copper		blue solution
+	➔	+
nitric acid		brown gas

Adding nitric acid to copper metal is one way to produce the blue colour from copper metal.

In Activity 1 you can try another way.

Elements are substances which cannot be broken down chemically into simpler substances.

An **atom** is the smallest part of an element, as far as chemical reactions are concerned.

A **compound** is made up of a combination of elements.

CELLS AND CHARGES

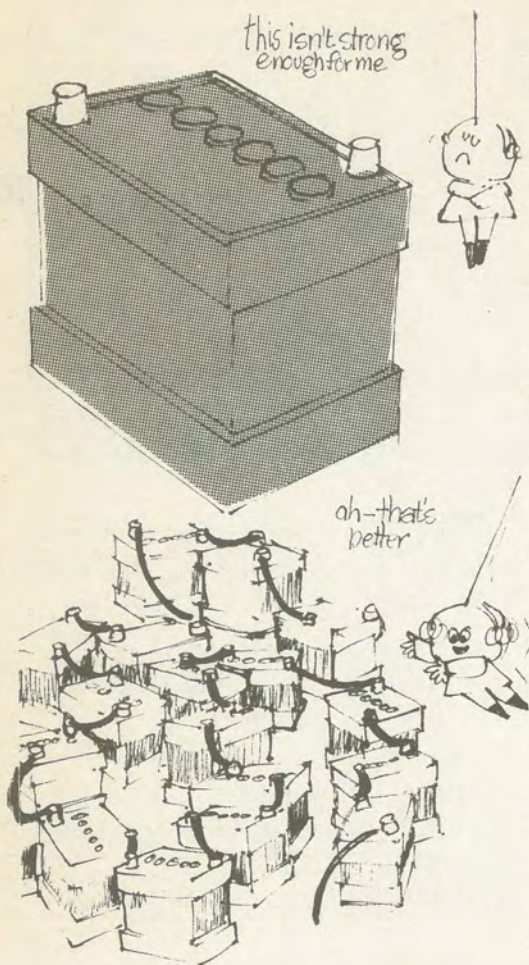
Collect a number of electric cells or a power-pack. The connecting ends of cells and power-packs are called **terminals**. One terminal has a plus sign (+) marked on it; and the other terminal has a minus sign (-) marked. Sometimes the + terminal is painted red and the - terminal is painted black. These signs, positive (+) and negative(-), mean there are a lot of positive charges on one terminal and a lot of negative charges on the other.

These charges are like the ones which you tested in earlier activities. You found out then that positive charges attracted negative ones and you detected charges easily by using a tester. So you may expect cell terminals to be able to attract testers. One cell is not strong enough to do this, but very many cells joined together (a battery) can attract light balls (Poly).

When connecting electric cells together to form a battery, you should connect a positive terminal to a negative terminal (or negative to positive).

Moving charges in a conductor make up an **electric current**.

Charges do not move by themselves. A cell or battery or a power pack has to 'push' the charges. You can see this for yourself in Option 4 (Electric Cells).



ACTIVITY 1: MAKING BLUE COLOUR— PART 1

You will need:

Part 1

- 1 power-pack*, set at 6 V
- 3 connecting wires with alligator clips
- 2 vials, and plasticine for support
- dilute sulphuric acid
- 2 copper strips
- 1 globe, 6.3 V, 0.25 A, and globe holder.

Part 2

- 1 heater
- 1 tripod and gauze mat
- 1 evaporating basin
- steel wool.

2

Clean the copper strips with steel wool.

Bend the copper strips over the edges of a vial. Leave about 1 centimetre of space between the end of the strip and the bottom of the vial. Make sure that the copper strips cannot touch each other.

Three-quarters fill the vial with acid.

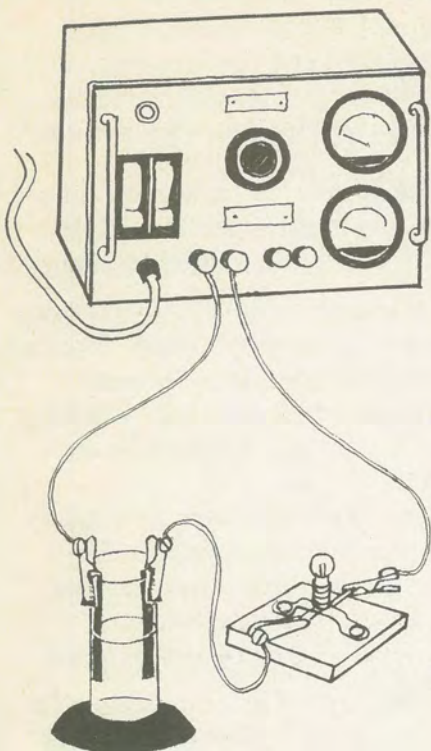


**ACIDS CAN BE DANGEROUS
SO BE CAREFUL.** If you spill
acid, wipe it up immediately
and wash the area thoroughly
with lots of water.

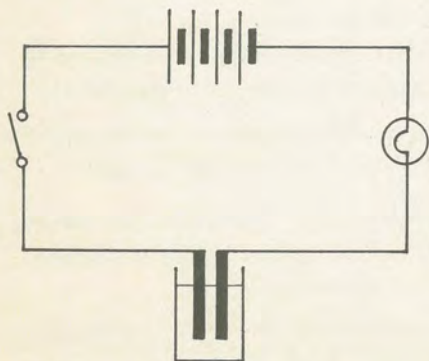
Use the alligator clip to connect a torch globe and the copper strips to the power-pack. (The power-pack contains a built-in switch.)

Do you know how to strip the insulation from the connecting wire? If you don't, ask a teacher to show you, or see the ASEP film loop *Stripping Wire*.

* A power-pack has a built-in switch. If you use electric cells or a battery instead, you will need a switch and an extra connecting wire to put in the circuit.



Equipment set up for the investigation.



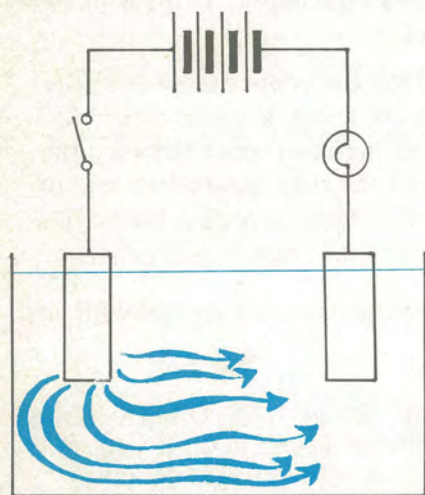
Circuit diagram of equipment.

Activity 1—Part 1 continued next page

Check to see if your circuit is correct.

You should also check all connections. Are they firm? Switch on. If the globe lights up, all is well. Otherwise check the connections and the circuit again. It could be that the globe is faulty.

Leave on for about two minutes.



 2.2 Look at both copper strips and in particular look at the liquid. Can you see anything changing?

There may be bubbles of gas rising in the solution. Don't worry about an explanation for these at present. The water which was used in making the solution has something to do with it.

The blue streaks seem to wander from the 'in' copper strip, which is connected to the positive terminal, over to the 'out' strip, which is connected to the negative terminal.

 2.3 How can you check that this is really what is happening? Try to find out for yourself.

Note: Put your vial and solution aside for the time being. You will use them again soon.

When you are clear what to do to investigate the blue streaks, do it!

You will probably need a clean vial and fresh, dilute sulphuric acid.

 2.4 Does the blue colour appear if the power-pack or battery is not connected?

Rinse the copper strips in water, then take fresh, dilute sulphuric acid and try it.

ACTIVITY 1: MAKING BLUE COLOUR— PART 2

The solution that you put aside, in Part 1, is probably only a faint shade of blue. To make it more blue, re-connect the original circuit and leave the current on until the positive strip has been used completely. This may take an hour or even longer. While waiting you could start Activity 2 (What Is the Blue Colour?), page 48.

2

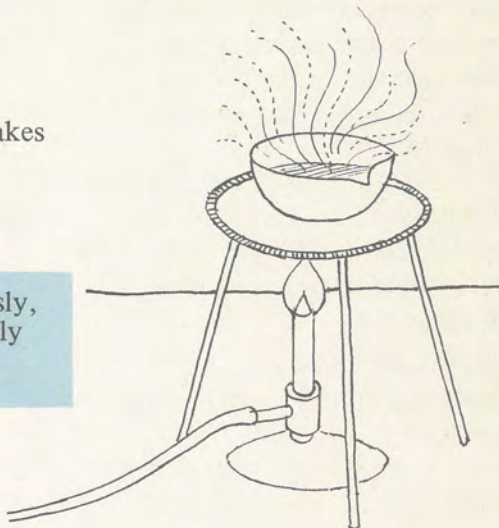
The blue colour will probably look similar to the blue solution which is formed when copper dissolves in nitric acid.

Transfer the solution to an evaporating basin.

Gently heat the liquid and evaporate about half of it. This makes the solution more concentrated.

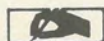


Warning: If heated too vigorously, the liquid may 'spit', and possibly hurt you.



Set the basin aside and look at it the next day. While waiting you could finish Activity 2 (What Is the Blue Colour?), page 48, and start Activity 3 (Investigating the Blue Crystals), page 50.

When you look at the basin again, you will probably find that the crystals have formed. If they haven't, evaporate some more liquid and let the solution stand for another day.



2.5 Can you find a substance like the crystals? What is it called?

ACTIVITY 2: WHAT IS THE BLUE COLOUR?

This is a reading activity.

'Copper' in solution is not pinkish brown like copper metal; it is blue. You did not see any copper metal move in Activity 1 (Making Blue Colour), page 46, but you did see blue streaks going across to the negative terminal.

You found earlier that negative charges attract positive charges. It is reasonable to guess that there are positive charges in the blue streaks.

We need a new name for these positive particles which wander through the liquid. The great British scientist, Michael Faraday (1791–1867), invented one. He used the Greek word for wanderer, *ion*. The positively charged particles which make the blue streaks are called copper ions.

Copper Atoms and Ions

How can a copper atom become a copper ion?

When scientists are asked such a question they try to answer it by playing a sort of game: 'If . . .'

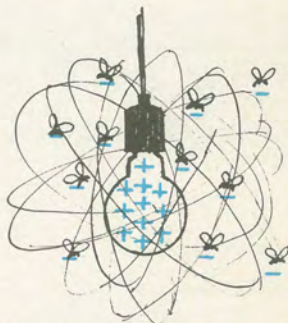
You can play it, too.



What could happen if atoms were like tiny, positive lights with swarms of negative insects zooming in clouds around the lights?

This sounds fanciful and it is. Even so, the idea can be used to explain how a copper atom forms a positive copper ion.

To fit in with what you know about uncharged materials, the number of insects (negative charges) would balance the positive charges on the light.

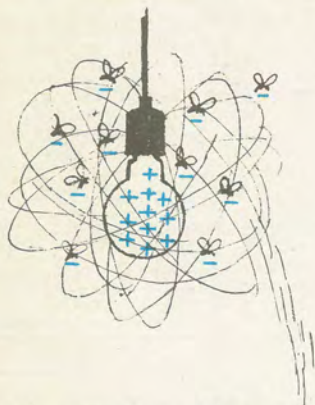


An uncharged atom—eleven positive charges and eleven negative charges.

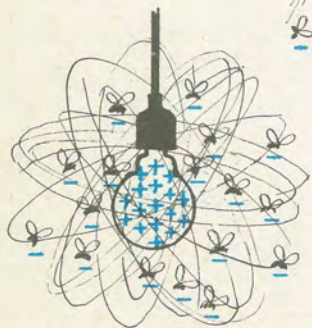
If another light were present, a negatively charged insect might easily fly across to it. The first light would then be positively charged—a positive ion!

The second light, because it had gained a negatively charged insect, would be negatively charged—a negative ion!

It could be that in some way atoms lose one or more negative charges to other atoms. As a result positive and negative ions would be formed.



A positively charged ion—eleven positive charges but now only ten negative charges.



A negatively charged ion—seventeen positive charges and one extra negative charge.

Why tell fairytales about lights and insects? You know what lights and insects are like; you have seen them often enough. Have you ever seen an atom? Of course not. Atoms are much too small. By thinking in terms of things which you know well, you can suggest how other things may behave even though you cannot see them. **2**

If you read pages 16 to 18 you will realize that this is yet another example of a model.

You can think of atoms as being made up of some parts which are positively charged and others which are negatively charged.

The negatively charged parts are called electrons. Perhaps you have heard of them.

Activities you will do in later years will allow you to decide whether this model is useful or whether it needs improvement.

In Option 5 (Will Any Liquid Do?), page 73 you can find out what happens to other atoms which gain electrons.

Can ions become atoms? If you want an answer to this question, you can do Option 3 (Putting on a Shiny Coat), page 54.

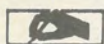
Did the blue crystals which were formed in your basin when you cooled the hot solution look like copper sulphate? That is just what they are.

ACTIVITY 3: INVESTIGATING THE BLUE CRYSTALS

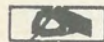
For this investigation, you will need:

- fine crystals of copper sulphate, about $\frac{1}{2}$ teaspoonful
- 1 strip A and cotton material
- 1 strip B and nylon material
- several foam spheres (plasticine or plastic spheres)
- filter paper.

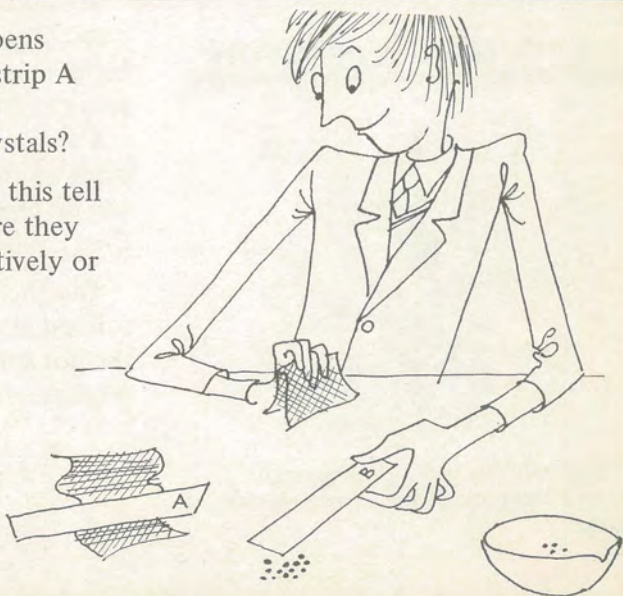
Dry your crystals carefully. To do this put your crystals on one piece of filter paper, put another piece on top and pat them dry. (For this activity you may need to crush your crystals when they are dry.)



2.6 What happens when you hold a charged strip A and strip B in turn, about 1 centimetre above the crystals?



2.7 What does this tell you about the crystals? Are they charged positively or negatively or are they uncharged?



In Activity 1 (Making Blue Colour), page 45, and in Activity 2 (What Is the Blue Colour?), page 48, you saw evidence of positive copper ions in a solution of copper sulphate.

In this activity you have found solid copper sulphate crystals to be uncharged.

Since uncharged materials have equal numbers of opposite charges it is reasonable to assume the copper sulphate crystals (as well as copper sulphate solution) contain positive copper ions and an equal number of negative ions—sulphate ions.

Copper sulphate crystals are hard. The copper ions and the sulphate ions hold on to each other very strongly. There is a force of attraction holding them together. In solution the ions are separated and this force is less so that the ions can 'go their separate ways'.

You could build a physical model of copper sulphate out of foam or plastic spheres or out of plasticine. Keep in mind that each positive ion attracts a negative ion.

Your model of a crystal will be crude, but it will do for a start. It will be like a vintage car when it is compared with the latest sports model. Your model will only be a beginning.

2



In an uncharged substance the sum of the negative charges must equal the sum of the positive charges.

Does this mean that a crystal actually has equal numbers of oppositely charged ions with the same amount of charge on each ion?

Couldn't some atoms lose or gain more than one electron to form ions? Surely a positive ion with two + charges combining with two ions each of one - charge will give an uncharged material?

TEST YOURSELF—WHAT IS BLUE?

Answer the following questions in your notebook.

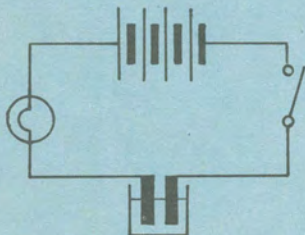
- 1 An atom which has lost an electron is called a

- A positive ion.
- B negative ion.
- C neutral ion.
- D neutral atom.

Questions 2 to 4 refer to the circuit diagram below.

The circuit diagram below shows a battery, a switch, a globe and a container of dilute sulphuric acid. Two copper strips stand in the container of acid.

When the switch is closed, blue streaks appear in the solution.



- 2 The blue streaks observed are due to

- A copper atoms.
- B copper ions.
- C electrons.
- D sulphate ions.

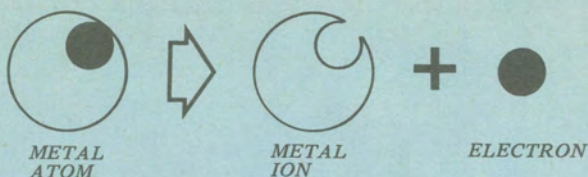
- 3 Suppose that the container of sulphuric acid is replaced by a container of dry copper sulphate crystals. How large would the current be then?

- A A bit larger than before
- B The same as before
- C A bit smaller than before
- D Zero

- 4 If, as in question 3, the sulphuric acid is replaced by dry copper sulphate crystals, the crystals would be attracted by

- A the positive strip only.
- B the negative strip only.
- C both the positive strip and the negative strip.
- D neither the positive strip nor the negative strip.

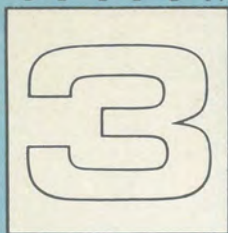
Questions 5 and 6 refer to the diagram below.



- 5 The metal atom is
- A uncharged.
 - B positively charged.
 - C negatively charged.
- 6 The metal ion is
- A uncharged.
 - B positively charged.
 - C negatively charged.
-
- 7 Which one of the following statements about scientific models is **not** true?
- A Models use familiar things to help us understand unfamiliar ideas.
 - B There may be several different models used to try to explain the same thing.
 - C Models may be changed as more evidence is gathered.
 - D By using models, scientists are able to give true descriptions of nature.

Now turn to Check Your Answers on page 102.

OPTION



Putting on a Shiny Coat

Before you begin this option you may have to do the test on page 110. Check with a teacher.

At the end of this option you will probably be able to:

- ☐ Use the terms 'electrode' and 'electroplating'.
- ☐ Use suitable electrodes and solutions and set up a circuit which works.
- ☐ Deposit a metal on an electrode.
- ☐ Report on the uses made of electroplating.

You will need to do Activity 1 completely, but you can leave out some of the later ones if you wish.

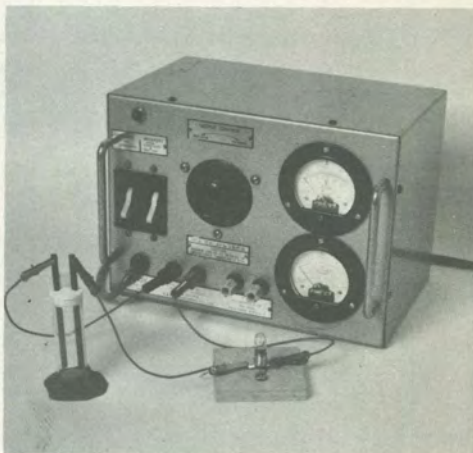
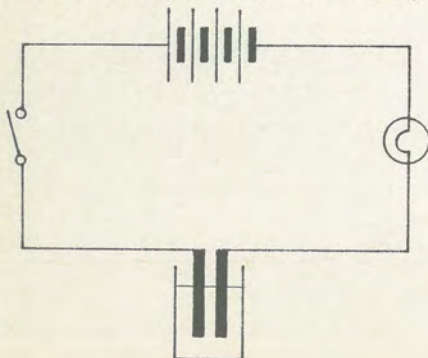
ACTIVITY 1: GETTING COPPER OUT OF COPPER SULPHATE

You will need:

- 2 small carbon rods
- 3 connecting wires, with alligator clips
- 1 globe, 6.3 V, 0.25 A, and globe holder
- 1 vial, and plasticine for support
- solution of copper sulphate
- 1 power-pack*, set at 6 V

To test for copper:

- 1 vial
 - concentrated nitric acid
- (These may be kept in a special section of the room. Ask a teacher about them.)



* A power-pack has a built-in switch. If you use electric cells or a battery instead, you will need a switch and an extra connecting wire to put in the circuit.

When connecting electric cells together to form a battery, you should connect a positive terminal to a negative terminal (or negative to positive).

Something To Read While You Wait.



Set up a circuit as shown in the photo and in the circuit diagram.

Make sure that the vial cannot fall over. You could use a plasticine base.

Check all connections carefully before you switch on.

Make sure that the two carbon rods cannot touch.

Three-quarters fill the vial with copper sulphate solution.

Switch on for two to three minutes. The lighted globe shows that an electric current is passing through the copper sulphate solution.

You can read the next section while you're waiting.

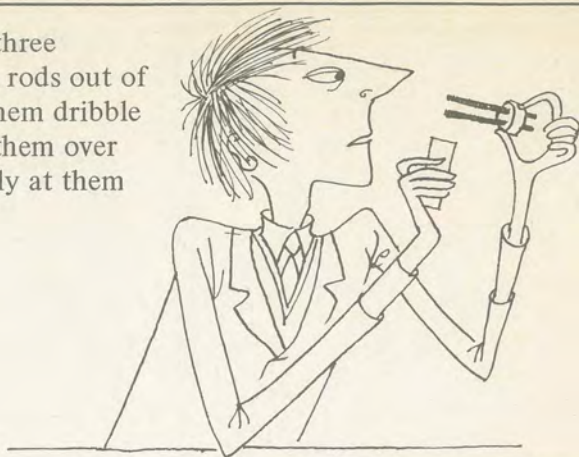
Your great-great-great-grandfather 200 years ago would have been amazed to see something light up, merely by connecting it to a box! Even today people in many countries have never seen a light globe and know nothing of electric currents.

Just imagine what your life would be like if, after dark, you had only a dim, smoky lamp. It is not only the light which you would miss. How many switches have you pressed since you got up this morning?

Make a list of all the electric appliances which you will be using today. Many switches have been pressed for you, too. For example, did a tram or train driver start a motor which was pulling a carriage bringing you to school?

Did you come by bus or car? The engine of the bus or the car would not have worked without an electric spark. The spark ignites the petrol vapour-air mixture in the cylinder and you would soon notice if it failed. (Diesel motors do not need sparks.)

Switch off after two to three minutes. Lift the carbon rods out of the solution. Don't let them dribble all over the place. Hold them over the vial and look carefully at them



 3.1 In your notebook, describe what the one which was connected to the positive terminal looks like?

 3.2 Is the other one different? If so, in what way?

Did you guess that the deposit on the negative terminal was copper?

Stop! A pinkish brown powder could be almost anything, even just a bit of dirt. A test will be necessary to decide if it is copper.

If you haven't done Option 2 (What Is Blue?), turn back to page 43 to find out what nitric acid does to copper.

Test the pinkish brown coating on the carbon rod in the same way and see if you get a similar reaction.

 3.3 Record the results in your notebook.

 3.4 Try to design a test to find out if the electric current was necessary to coat the carbon.

Take the copper coat off the carbon rod. The easiest way to do this is to connect the coated carbon rod to the positive terminal and the other to the negative terminal.

 3.5 What happens if you leave the current on for ten minutes or longer?

 3.6 Where did the copper come from?

You can check your suggestions by leaving the current on overnight.

 3.7 Describe what you notice the next morning. Does it fit in with your suggestions? If not alter your suggestions in light of this new evidence.

In this activity you have seen that **energy** is needed to move charged things. The energy which can be supplied by a power-pack or battery was used to change copper ions to copper atoms.

ACTIVITY 2: COPPER-PLATING

You can put a thicker coat of copper on various articles as well as on carbon.

A metal plate (or carbon rod) which is connected to a battery and dips into a suitable solution is called an **electrode**.

Putting a coat of metal on to an object by electrical means is called **electroplating**. So far in this option you have put copper coats on—you have been copper-plating.

To Copper-plate the Article

Connect the copper foil to the positive terminal at point X. (See diagram.) You have made copper the positive electrode.

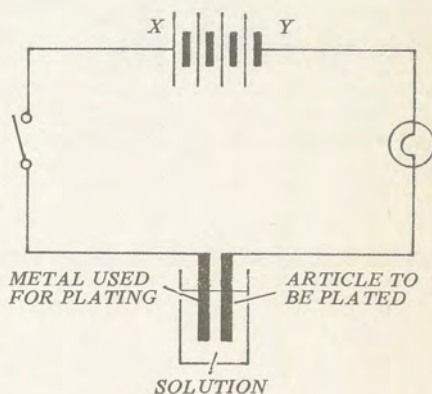
Connect the object to be coated to the negative terminal at point Y. You have made the object the negative electrode.

Three-quarters fill the vial with copper sulphate solution.

Switch on and leave until you get a good coat of copper on the object.

You will need:

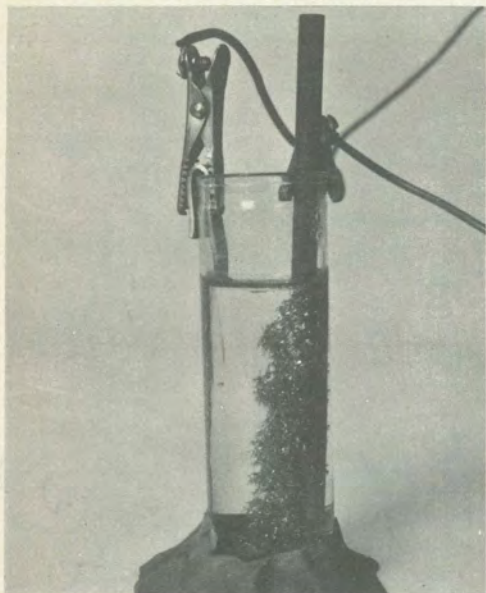
- 1 piece of clean copper foil (or a twist of copper turnings, or a copper plate)
- 1 article to be copper-plated, e.g. an old key
- 3 connecting wires, with alligator clips
- 1 vial and plasticine for support
- copper sulphate solution
- 1 power-pack, set at 6 V
- 1 globe, 6.3 V, 0.25 A, and globe holder
- steel wool.



It is likely that the copper coat will not stick to the article. Try cleaning the article with steel wool first of all. It may help.

In industry, special preparation of surfaces and control of the reaction are vital if a permanent coat is to be obtained.

ACTIVITY 3: LEAD-PLATING



Feathers of lead crystals forming on a carbon electrode after ten minutes at a 6 volts setting of a power-pack, using a current of 0.4 amperes.

You will need:

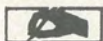
- 1 strip of lead foil
- lead nitrate solution (**poisonous**)
- 1 vial, and plasticine for support
- 1 carbon rod
- 1 power-pack, set at 6 V
- 3 connecting wires with alligator clips
- 1 globe, 6.3 V, 0.25 A, and globe holder.

Set up a circuit with the lead foil and the carbon rod as electrodes. Bend the lead over the edge of the vial.

Take care. Which electrode should the lead be? Positive or negative? Think back to the previous activity. Which electrode was the copper?

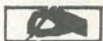
Be sure the electrodes are not touching.

Switch on and leave on for two to three minutes.

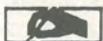


3.8 Draw your circuit diagram in your notebook while you wait.

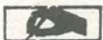
When the two to three minutes are up, switch off and look closely, through the lead nitrate solution, at the electrodes.



3.9 In what way, if any, did the positive electrode change?



3.10 In what way, if any, did the negative electrode change?



3.11 Switch on again for 10 to 15 minutes and then describe what you see during this time.

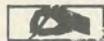
ACTIVITY 4: A MAGNESIUM COATING?

You will need:

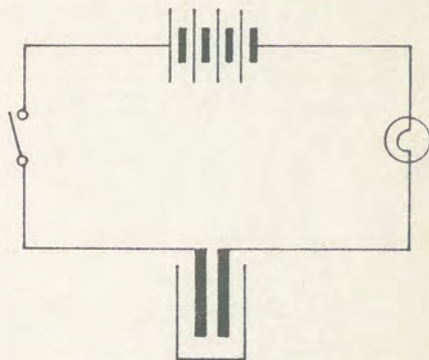
- magnesium sulphate solution
- 1 vial, and plasticine for support
- 1 strip of magnesium ribbon, about 8 cm long
- 1 carbon rod
- 1 globe, 6.3 V, 0.25 A, and globe holder
- 1 power-pack, set at 6 V
- 3 connecting wires with alligator clips
- 1 small beaker
- 1 heater and gauze mat.

Connect the circuit as shown.

Three-quarters fill the vial with magnesium sulphate solution and switch on the current for about five minutes.

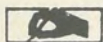


3.12 What happens during this time?



3

Now switch off, and look closely at the magnesium and carbon electrodes, and at the solution.



3.13 Record your observations in your notebook.

Heating increases the rate of many reactions. Pour the solution from the vial into a small beaker and heat it. (Don't let it boil).

When it is hot (as bubbles first appear), pour it back into the vial and repeat the investigation.



3.14 What do you notice this time?

The white, insoluble substance is called **milk of magnesia**. You may

have taken milk of magnesia for a stomach upset. It is also used in some toothpaste.

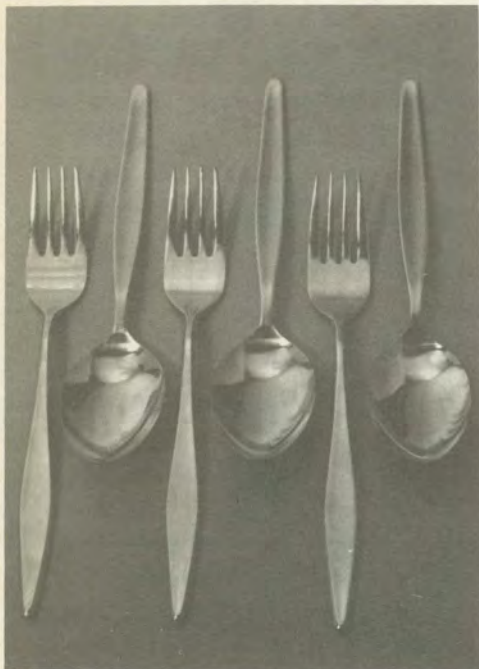
Check toothpaste and stomach powder labels to find out.

This activity shows that magnesium is different from the other metals you have been using. You cannot use it for plating.

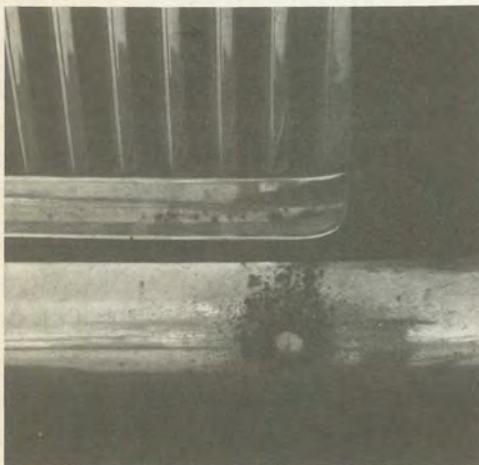
In Other Things You Could Do at the end of this option (page 63), you can try plating with other metals and solutions.

ACTIVITY 5: ELECTROPLATING

This is a reading activity.



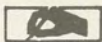
Silver-plated cutlery.



Rust coming through the chromium plating on a bumper bar.

Electroplating is done either to make things look more beautiful or to protect them, or both.

Next time you handle a 'silver' spoon or a 'silver' tray, look for the letters EPNS. You will probably see them somewhere on the article. These letters stand for electroplated nickel silver.



3.15 What substances, do you think, would be needed to silver-plate a nickel spoon?

Silver

Many people think that silver is beautiful, but silver is expensive and so cheaper metals are often silver-plated.

Apart from being expensive, silver becomes dull easily. It becomes tarnished and has to be polished. This can be a tedious job. To protect the silver shine some modern silver jewellery is plated with a metal called **rhodium**, which does not tarnish.

Bumper Bars

Steel bumper bars on cars are protected by nickel- and chromium-plating. Look at a bumper bar which has been dented badly. If the car is an old 'bomb', you will see that the bumper has become rusty where the protection has been knocked off.

You could try to find out more about chromium-plating. You could find out how it is done industrially, and report to the other students.

Gramophone Records

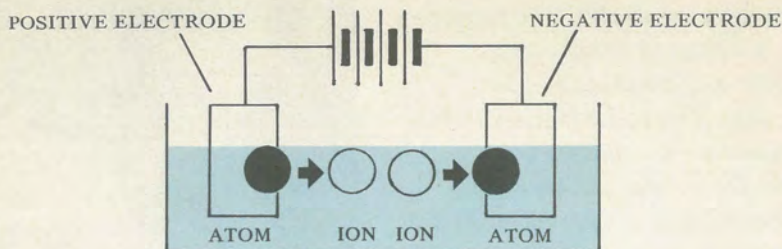
You probably own some gramophone records. When a recording is made, a diamond needle cuts a groove into an aluminium or wax 'master' disc. The records have to be exact copies of this master disc otherwise the sound will be wrong.

The master disc is covered with a conducting solution and put into a bath containing nickel in solution (nickel ions). The master is connected to the negative terminal of a power supply, and the positive terminal of the supply is joined to a nickel plate. Nickel is plated on to the master and there forms a skin. This skin is peeled off. The skin has ridges where the master had grooves. Now a plastic blank is pressed on to the rigid skin—and you can buy your record.

Try to find out more about making records.



A nickel-plated master disc.



WHAT HAPPENS DURING ELECTROPLATING?

In the work which you have done and in the industrial processes which were mentioned, there were two main requirements.

1 Metal ions in solution became metal atoms on the negative electrode.

2 Metal atoms from the positive electrode became metal ions in solution. These replace the metal ions deposited from solution on to the negative electrode.

An ion is an atom which has become positively or negatively charged. Ions of a metal always carry positive charges and behave very differently from the metal atoms.

In all the activities you had to do one thing which was the same—you had to connect the electrodes to a power-pack. If you used a battery instead, you probably found that it became exhausted. The electrical energy in the battery was used up.

Energy changes were involved in converting

- ☐ metal atom to metal ion and
- ☐ metal ion to metal atom and
- ☐ in transporting ions between the electrodes.

If you have been using a power-pack, the school will have to pay for the electrical energy you have used.

OTHER THINGS YOU COULD DO

Find out the answers to these questions in your own way and write reports in your notebook.



1 Does the time for a deposit to appear depend upon the distance between the electrodes?



2 If you dissolve two more spoonfuls of copper sulphate crystals in the copper sulphate solution (available for Activities 1 and 2), do you get a deposit more quickly? What happens when even more is added?



3 Does the strength of the current influence the amount of deposit in a given time for a given separation of the electrodes?



4 What is anodizing? Can you do it?

POSITIVE ELECTRODE	NEGATIVE ELECTRODE	SOLUTION	RESULT
COPPER	CARBON	COPPER SULPHATE	PINKISH BROWN COATING ON THE CARBON

5 You can try plating with various metals and solutions.

List your findings in your notebook in a table like the one shown above.

Hint: Tin gives interesting results.

TEST YOURSELF—PUTTING ON A SHINY COAT

You are not being asked questions on what you know here. Instead you are going to see what you can do. Your job will be to put a nickel coating on a nail.

Instructions:

- ☐ Work on your own.
- ☐ Do not use your books or notes.
- ☐ Choose the equipment and chemicals you think you will need to nickel-plate a nail.
- ☐ Set up your equipment.
- ☐ See a teacher before you start the nickel-plating.

Now turn to Check Your Answers on page 105.

OPTION



Electric Cells

Before you begin this option you may have to do the test on page 110. Check with a teacher.

At the end of this option you will probably be able to:

- ☐ Use the terms 'electric cell', 'battery' and 'storage cell'.
- ☐ Make your own electricity supply.
- ☐ Report on the various portable sources of electric current.

If your torch goes dim, or if your transistor radio fades, you buy a new 'battery'. Now you can find out what makes a 'battery' work.

Electrical energy can bring about chemical changes. If you have done Option 3 (Putting on a Shiny Coat), you have seen this for yourself.

Can chemical changes produce electrical energy? Keep going and you will find out.

You can make an electric cell in each of the Activities 1, 2, 5 and 6. Perhaps different groups could make different cells and compare them.

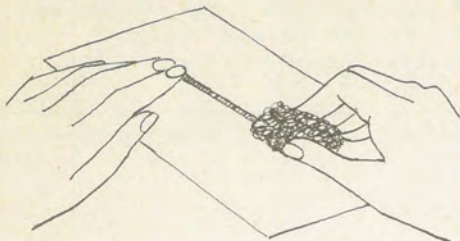
ACTIVITY 1: MAKING A MAGNESIUM CELL

You will need:

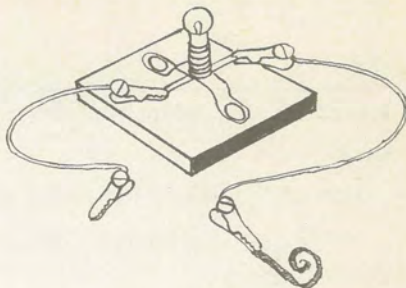
- magnesium ribbon, about 15 cm
- 1 small, empty can—some food cans are suitable (or 1 nickel crucible)
- 1 globe, 1.25 V, 0.25 A, and globe holder
- 2 connecting wires with alligator clips
- solution of copper sulphate (or copper chloride)
- steel wool and paper towels, to clean magnesium and the can.



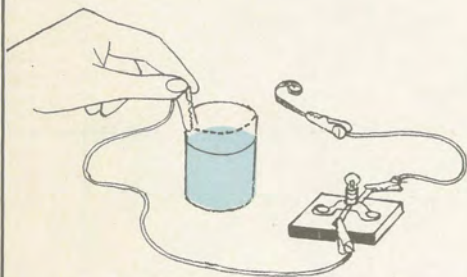
1 Take about 10 centimetres of the magnesium ribbon and clean it with steel wool until it is shiny.



2 Then curl up the magnesium ribbon and connect it to the globe as shown.

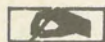
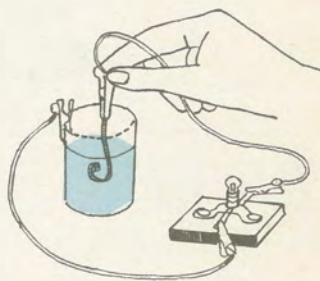


3 Three-quarters fill the can with copper sulphate (or copper chloride) solution. Connect the alligator clip of the second connecting wire, to the can.



4 Dip the magnesium into the liquid.

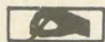
Make sure it does not touch the can or the other clip.



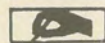
4.1 In your notebook describe the changes you observe. Be sure to feel the can with your fingers.

You have just made an electric cell. It may not last for very long. While the strong chemical reaction is going on you can draw electrical energy from the cell.

When the cell runs down you can see whether it can be 'freshened up'. Try using another small piece of magnesium ribbon.



4.2 What happens?



4.3 Try other ways to start the cell again. Were you successful? What did you do?

ACTIVITY 2: MAKING A COPPER- ZINC CELL

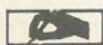
You will need:

- 1 clean copper plate (or copper foil)
- 1 clean zinc plate (or zinc foil)
- 1 globe, 1.25 V, 0.25 A, and globe holder
- 2 connecting wires with alligator clips
- 1 vial, and plasticine for support
- copper sulphate solution (or dilute sulphuric acid).

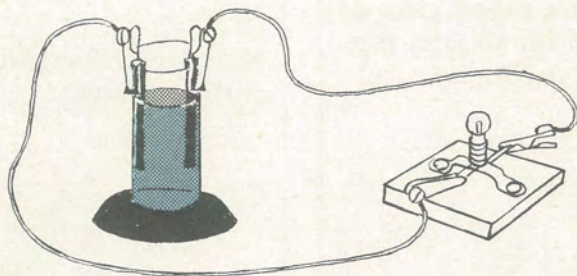
Attach the zinc plate and the copper plate to the vial as shown in the diagram.

Join the plates to the globe in its socket.

Three-quarters fill the vial with copper sulphate solution (or dilute sulphuric acid).



4.4 Do you get any light? What happens around the copper plate? What happens around the zinc plate?



Copper, copper sulphate or dilute sulphuric acid and zinc when placed together behave like the torch cells which you can buy—they supply electrical energy.

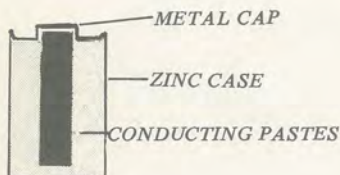
What is an electric cell? There is a way of describing a cell according to what it does. A cell is a combination (system) of two conducting plates (probably made of carbon and/or different metals) and a conducting liquid. Together they supply an electric current if they are in a closed circuit.

ACTIVITY 3: CELLS AND BATTERIES

This is a reading activity.

You know that your torch cell behaves in a way similar to the cells you have made. To find out what is in a torch cell you can cut one open. This is a messy job and can be done with a hack-saw.

In the cells you have been making and in commercial cells there are two different conducting materials, and changes can be seen when the cells are working. In both groups, the cells contain a conducting liquid, and both 'run down' sooner or later. (In some cells the conducting liquid is more like a jelly.) Chemical energy is used up to give electrical energy which will light up a globe.

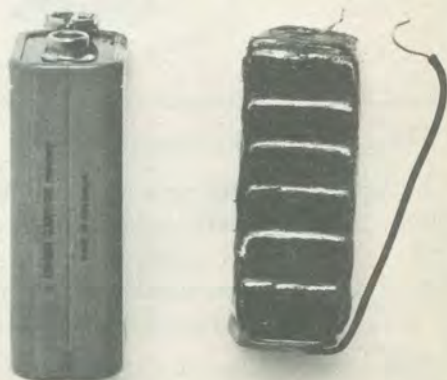


Several cells together are called a **battery** of cells. This word was suggested by Benjamin Franklin. The cells acting together reminded Franklin of an artillery battery. Many people use the word 'battery' for a single cell, such as the one in your torch. This is not correct, but there is no point in being too fussy about it.

Sometimes the torch cell is called a dry cell. If it were really dry it would not work. Can you suggest why?

The cells you made had a liquid electrolyte, such as copper sulphate solution. In the dry cells this is replaced by a jelly-like paste. Sometimes it used to leak out when the cell was old. This is why you see advertisements claiming a 'leak-proof case'. This jelly is made up from manganese dioxide, ammonium chloride, water, glue and flour. The dry cell made a big difference to our ways of living because it gave us portable electricity.

- You may know someone who uses a hearing aid. It will have an incredibly tiny battery inside.
- A tiny machine which keeps some faulty hearts beating is called the pace-maker. The pace-maker is also powered by a tiny cell.
- A really dry cell is used in air-sea rescue. But it works only when dropped in sea water. Can you work out why this is useful? Can you make one?



A nine volt battery cut open showing the individual cells.

ACTIVITY 4: MAKING A STORAGE CELL

When the chemical energy in the cell materials is used up, you get no more electrical energy for your torch globe or your transistor radio and you might as well throw the cell away. Car batteries and boat batteries should not be thrown away like this.

Have you ever tried to carry a car battery? They are very heavy. This is not surprising. They have lead plates inside. In this activity you can make a similar battery.

You will need:

- 1 vial, and plasticine for support
- 2 connecting wires, with alligator clips
- sodium sulphate solution, enough to three-quarters fill the vial
- 1 power-pack*, set at 6 V
- 1 globe, 1.25 V, 0.25 A, and globe holder
- 2 lead plates (or strips of lead foil).

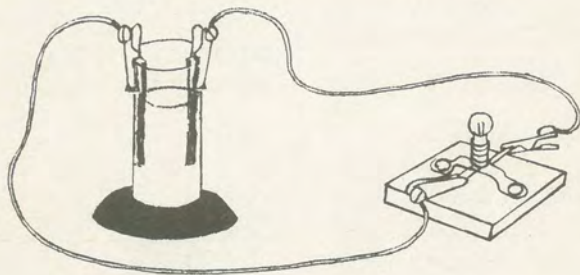
* A power-pack has a built-in switch. If you use electric cells or a battery instead, you will need a switch and another connecting wire to put in the circuit.

When connecting electric cells together to form a battery, you should connect a positive terminal to a negative terminal (or negative to positive).

Put two pieces of lead in the vial and separate them by a stiff board, or by clamping in some way so that they do not touch each other.

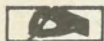
Connect the pieces of lead to a globe.

Three-quarters fill the vial with sodium sulphate solution.



The globe doesn't light up.

In Activity 1 (Making a Magnesium Cell) the connecting wires were joined to magnesium ribbon and to the metal can. In Activity 2 (Making a Copper-Zinc Cell) copper and zinc metals were connected to the wires, i.e. in both cases, **different** metals were used.



4.5 What is different in this case?

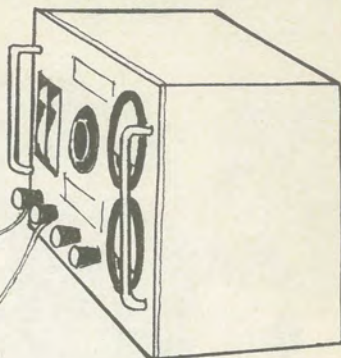
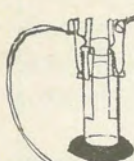
If car batteries use lead plates, then something must be done to make the battery work. It must be **charged**.

Remove the globe and holder and connect the lead plates to a power-pack as shown in the diagram.

Switch on for one to two minutes.



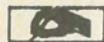
4.6 What do you notice during this time?



When you switch off the power-pack, look carefully at the lead plates. You may need to remove them from the liquid.



4.7 What happened to the lead plate connected to the positive terminal?



4.8 What happened to the lead plate connected to the negative terminal?

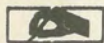


4.9 Did you notice anything about the liquid?

4

The electric current from the power-pack has brought about chemical changes. The electrical energy from the power-pack has been stored as chemical energy on the plates. The plates have been charged with energy.

Does this charge the cell so that it will work? Connect the globe to the plates and see.



4.10 Does the globe light up? If so, for how long?

If the globe does not light up, try charging for a bit longer. When the light goes out you say that the cell has gone **flat**.



Charging a car battery.



Testing a car battery for charge.

You can charge and discharge your cell frequently. It is called a **storage cell**. When you charged it, electrical energy is fed into the cell and changed into chemical energy. When you discharge, this chemical energy is changed again to electrical energy. It sounds great!

Do you have the feeling that once you have started, you can go on forever charging and discharging? Unfortunately, it is not as easy as that.

Did you feel the cell? It becomes hotter. Did you see the bubbles?

The heating and the bubbles (and some other things happening) make some of the energy useless to you.

Have you come across other examples of energy change? You have probably found that a 'tax' always has to be paid on the exchange. This seems to be a law of nature.

We can never usefully recover all the energy which we feed into devices like cells, motors, or petrol engines.

OTHER THINGS YOU COULD DO

Because of possible dangers involved, you should check your investigation plans with a teacher before you proceed.



1 You may like to test plates of various metals and the carbon rods to find out which combinations make electric cells. You could use a meter to tell if electrical energy is being produced.



3 How does the size of the plates (or strips) affect the performance of a cell?



2 Does the distance between the plates have any effect on the performance of a cell?

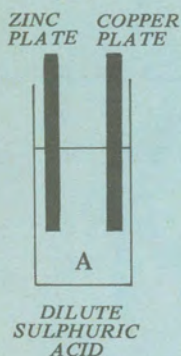


4 You may be able to borrow a battery tester. How does it work? You could also try to find out how a car battery becomes charged during driving.

TEST YOURSELF—ELECTRIC CELLS

Answer the following questions in your notebook.

- 1 Which one of the diagrams below shows a combination which forms an electric cell?



- 2 Suppose that a completely 'flat' storage cell is charged until it has 1000 units of energy. This storage cell is then used to supply electrical energy to a system of lights on a Christmas tree. How much electrical energy would be transferred from the storage cell to the system of lights before the battery would be completely 'flat' again?
- A Exactly 1000 units
 - B More than 1000 units
 - C Less than 1000 units
- 3 In which one of the following may we be sure that chemical energy is changed into electrical energy?
- A A length of nylon becomes charged as it moves over rollers.
 - B The battery in a parked car goes 'flat' when the lights are left on overnight.
 - C An electric cell is recharged by connecting it to a power supply.
 - D An electric radiator is used to heat a room.
- 4 List **three** important differences between a car battery and a torch 'battery'.

Now turn to Check Your Answers on page 106.

OPTION



Before you begin this option you may have to do the test on page 110. Check with a teacher.

At the end of this option you will probably be able to:

- ☐ Test whether a liquid is a good or a poor conductor of electricity.
- ☐ Use the term 'electrolyte'.

Will Any Liquid Do?

ACTIVITY 1: WHICH LIQUIDS CONDUCT?



If you have done Option 2 (What Is Blue?), Option 3 (Putting on a Shiny Coat), or Option 4 (Electric Cells) you will have found out about the things that happen to the electrodes which direct the current into and out of liquid.

- ☐ Does the liquid matter?
- ☐ Are all liquids conducting?

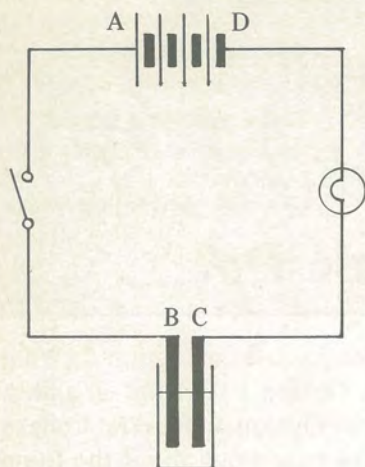
If you think that you can design an activity to find answers to these questions, forget about the instructions to help you with this activity.

Instead, write a few notes in your notebook saying what you intend to do. Get your investigation plan approved, close this book—and go ahead. You may like to work with a partner.

5

If you intend to follow the book, keep reading. Get together with others doing this activity from the book.

You may be familiar with the set-up which you are about to use. You may have used this particular circuit in other options. *Activity 1 continued next page*



For the circuit above there is a conducting path (a connecting wire) from point A through the switch (when closed) to point B and another such path from point C through the globe to point D. There will not be a current if there is no conducting path from B to C.

* A power-pack has a built-in switch. If you use electric cells or a battery instead, you will need a switch and an extra connecting wire to put in the circuit.

When connecting electric cells together to form a battery, you should connect a positive terminal to a negative terminal (or negative to positive).

You will need:

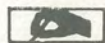
- 1 power-pack*, set on 6 V
- 1 globe, 6.3 V, 0.25 A, and globe holder
- 2 carbon rods
- 1 vial, and plasticine for support
- a selection of liquids, including distilled water
- 3 connecting wires, with alligator clips
- 1 wash bottle, to wash electrodes (or a container of water). This is so that you don't carry a liquid on from one test to the next.

You have found out that you need a power supply and a complete circuit for a globe to light up. You may have found out, in Options 2, 3 or 4, that some liquids can close the electrical gap from one carbon rod to another.

Now you can find out whether all liquids can serve as a pathway for an electric current.

You will use various liquids to try to close the electrical gap between B and C.

Set up a circuit like the one shown, using carbon rods. If you have difficulties trying to 'read' a circuit diagram, a friend who has 'read' one before could help.



5.1 One of your group should prepare a table like the one shown on the opposite page. Each member of the group could try a different liquid. After each test, dip the electrodes repeatedly into fresh water to wash off any solution.

At the end of the activity, copy the completed chart into your notebook.

LIQUID	OBSERVATIONS
DISTILLED WATER	
DILUTE ACID	
AMMONIA SOLUTION	
SOAP SOLUTION	
SUGAR IN WATER	
SALAD OIL	
SALT WATER	
<i>Do not write in this table</i>	
Ask a teacher to approve other liquids before adding them to the list.	

What Is Special about Conducting Solutions?

Each solution which carries a current is called an **electrolyte**. Tick the liquids which are electrolytes.

Look at your entry for distilled water. The lamp showed no current, but even a little bit of salt would make it conducting. Try it. Perspiration on your finger-tips is salty. Be careful never to have bare electric wires anywhere a person could touch them.

You cannot say much about some of the liquids. It could be that a more sensitive detector is needed to detect a current through them.

All the solutions used in Options 2, 3 and 4 are electrolytes. The lamp glowed in each case. All electrolyte solutions contain ions. In later years you may find out what the ions have to do with the current.

Many of the liquids in your body are electrolytes. Ions play a big part in the way in which nerve impulses travel. Nerve impulses carry messages from one part of the body to another.

ACTIVITY 2: LOOKING FOR IONS

This activity is mainly for students who worked through Option 2 (What Is Blue?) and enjoyed doing it.

So far you have met only positive ions, that is ions which are attracted by negative electrodes.

In many cases positive ions lose their positive charges and become uncharged atoms when reaching the negative electrode.

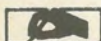
If you have done Option 2 (What Is Blue?), start at the top of page 77.

If you have not done Option 2, you should collect the equipment listed at the right and start here.

You will need:

- 1 strip A and cotton material
- 1 strip B and nylon material
- 1 teaspoonful of fine copper sulphate crystals.

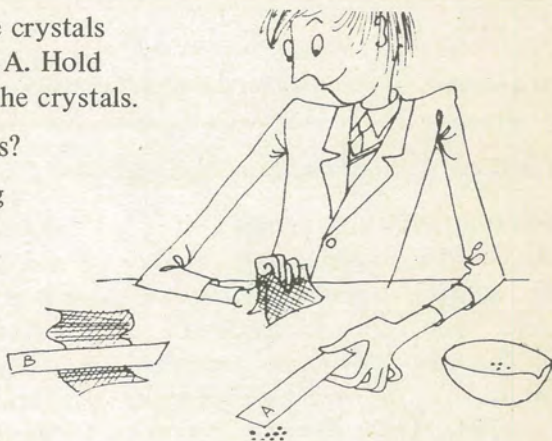
Sprinkle fine copper sulphate crystals on to paper. Charge the strip A. Hold it about 1 centimetre above the crystals.



5.2 What happens?



5.3 Repeat, using the charged strip B.



You probably found that both strips attracted the crystals. The crystals must be uncharged. You can say this because they are attracted by a positive and by a negative strip.

Positive ions are contained in copper sulphate crystals. Therefore, the crystals should contain negative ions to make them uncharged.

In this next section you use a different substance to find out about negative ions.

To find out something about negative ions:

You will need:

- 2 vials, and plasticine for support
- 1 globe, 6.3 V, 0.25 A, and globe holder
- 3 connecting wires, with alligator clips
- 2 carbon rods
- 1 power-pack*, set on 6 V
- a solution of sodium (or potassium) iodide—
sodium iodide is often added to table salt and is very like it
- starch solution
- a few crystals of iodine.

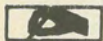
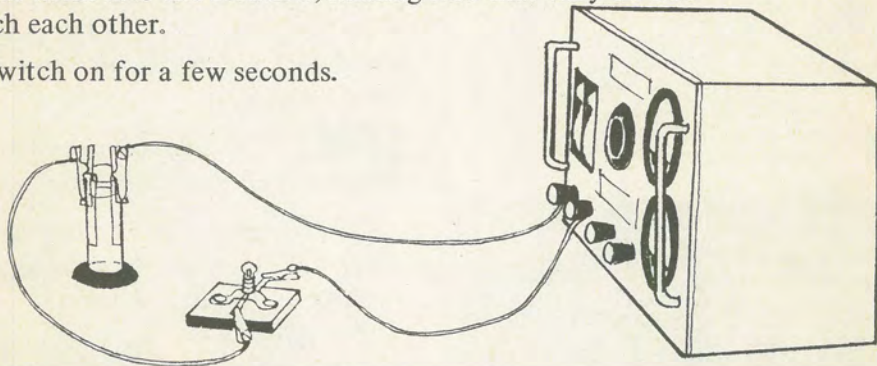
* See footnote bottom page 74 about power-packs.

Support a vial and three-quarters fill it with the iodide solution.

Connect the electrodes to the globe and the power-pack as shown.

Put them into the solution, making sure that they do not touch each other.

Switch on for a few seconds.



5.4 What changes can you see at the positive electrode?



5.5 What changes can you see at the negative electrode?

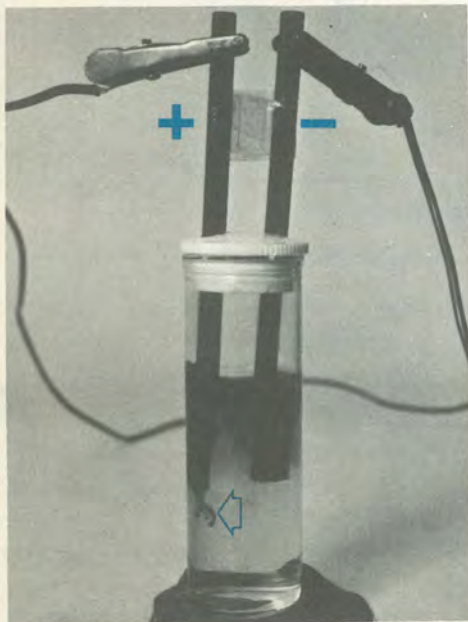
It has been suggested that positive ions can lose their charge and become uncharged atoms on reaching the negative electrode.

Can negative ions do a similar thing? Can they lose their negative charge on reaching the positive electrode?

Perhaps the brown colouring around the positive electrode is evidence of this. If this is so, the iodide ions from the sodium iodide solution should be changing to uncharged iodine atoms. To find out, you need to show that the brown colouring around the positive electrode is iodine.

A Test for Iodine

You may know of a test for starch where you use iodine. Every test can be used both ways. You could try the starch test to test for iodine.



Iodine? A blue-black colouring forms around the positive electrode and eventually drifts away and gives colour to the liquid.

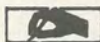


5.6 Half fill the other vial with starch solution. Add a few crystals of iodine. Shake up. What happens?

Start with fresh iodide solution in the first vial. This time, add a few drops of starch liquid to the solution.

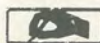


5.7 Is iodine present in the solution?



5.8 Connect the circuit as before and switch on for a few moments. What happens?

It seems that iodine has formed at the positive electrode. The iodide ions, from the iodide solution, must have been negatively charged. They lost their charge on reaching the positive electrode and became uncharged iodine atoms.

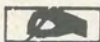


5.9 A prize question: 'What colour is an iodide ion?'

Other negative ions behave in the same way. They are discharged at the positive electrode to become uncharged atoms.

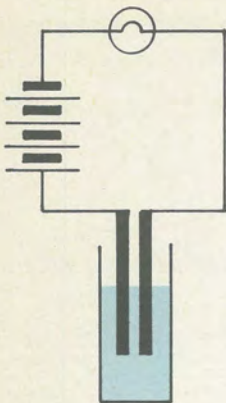
The story is more complicated for some negative ions such as sulphate ions, nitrate ions, and others. Also, there are the many positive metal ions that are not discharged in solution. But this is the kind of theory for which you must wait until later years.

You may like to test sodium iodide crystals for their charge. Hold the charged strips A and B about 1 centimetre above the crystals. Did both strips attract the crystals?



5.10 What did you find?

GLOBE DOESN'T LIGHT

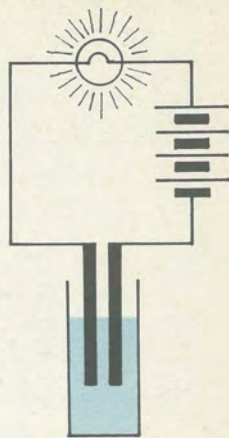


WITHOUT ELECTROLYTE

To bridge the electrical gap between electrodes a conducting solution (electrolyte) is needed.

An electrolyte contains positive and negative ions. When an energy source is connected in the circuit, the movement of these charged ions to oppositely charged electrodes 'makes' the circuit and allows a current to flow.

GLOBE LIGHTS



WITH ELECTROLYTE

OTHER THINGS YOU COULD DO

If you would like to do more with ions and solutions, here are some suggestions.



1 What changes occur when cobalt chloride solution and carbon electrodes are used in the circuit on page 74. Demonstrate and report to other students.



2 Use a galvanometer (if available) to compare the currents in the various solutions used in Activity 1. The meter is a much better indicator than a globe.

TEST YOURSELF—WILL ANY LIQUID DO?

Answer the following questions on a page of your notebook.

You are not only going to be asked what you **know** here, but also what you can **do**. Your first job will be to test whether a colourless solution is a conductor or not.

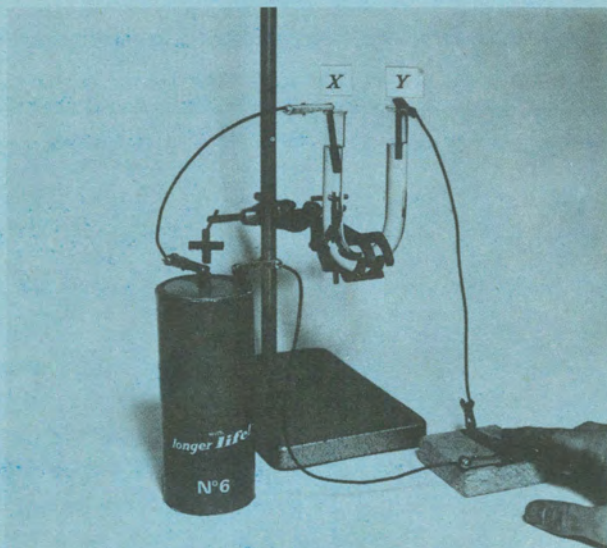
1 Instructions:

- ☐ Work on your own.
- ☐ Do not use your books or notes.
- ☐ Obtain a container of colourless solution from a teacher.
- ☐ Choose the equipment you think you'll need to find out whether the colourless solution is a conductor or not.
- ☐ Set up the equipment. See a teacher before you start.

Is the solution a conductor?

Questions 2 to 5 refer to the photo and information below.

The photo shows a U-tube containing sodium iodide solution and starch solution. Two metal strips X and Y (the electrodes) are placed in the U-tube as shown. When the switch is turned on, a blue-black colour appears in the U-tube.



- 2 The blue-black colour shows the presence of
- A sodium iodide.
 - B sodium.
 - C iodine.
 - D iodide ions.
- 3 Near which electrode would you **first** see the blue-black colour?
- 4 Sodium iodide crystals are
- A positively charged.
 - B negatively charged.
 - C uncharged.
- 5 Iodide ions are
- A positively charged.
 - B negatively charged.
 - C uncharged.
-
- 6 If an electric current is passed between two carbon electrodes placed in a concentrated solution of common salt (sodium chloride), a green gas called chlorine is given off at the positive electrode. Which **one** of the following best helps to explain why this happens?
- A Negative chloride ions from the salt solution move to the positive electrode and become atoms of chlorine.
 - B Chlorine gas is dissolved in the salt solution, and when an electric current is passed through the solution chlorine gas is forced out.
 - C Carbon ions leave the negative electrode and become uncharged atoms of chlorine at the positive electrode.
 - D When an electric current is passed through water or any solution containing water, gases are given off and one of these is chlorine.

OPTION



- At the end of this option you will probably understand a great deal more about the men who first experimented with electricity—and about the people among whom they lived.
- You may be able to write and produce a short play about these men and their families, and the rulers with whom they came into contact.

Whodunit?

BENJAMIN FRANKLIN, THE SEVENTEENTH CHILD

It is a great detective story—the gathering of clues about the people who gave us the use of electricity. There were many of these people but the only thing they had in common was their curiosity about new and different things.



In 1706, life in the thirteen British colonies in North America was in many ways similar to life in the Australian colonies about one hundred years later. The ruling class had close connections with the mighty capital of England, London, while the poorer settlers kept very much to themselves and had little to do with the ruling class.

People cheered when he passed

The child of a soapmaker could hardly look forward to a great career and yet Benjamin Franklin, the seventeenth child, became a celebrity. He loved to hear people in the streets cheer when he passed, or to have the most famous French portrait painter of that time to paint him and the most outstanding sculptor of Paris to make his bust.

In his childhood, there was not enough money in the Franklin family to send little Ben to school. He had to begin earning his living as quickly as possible. He was apprenticed to a printer. This apprenticeship was fortunate for the boy, who was keen to learn, because he had the opportunity to read books and to educate himself.

He made quick progress and when he was seventeen years old he sailed to London

to see the wonders of the big city for himself. He made many friends in London and heard about some of the scientific marvels happening in Europe. He had always been fascinated by science.

A leader in a fight

On his return, and when he was still only twenty, he started his own print shop in the town of Philadelphia. There was a great contrast between what he knew about the luxury of the King's Court in London and the way of life in this colonial city. He saw that this was an unsatisfactory state of affairs.

He wrote and published many political pamphlets, which were very popular. People actually tore them out of his hands as they were so anxious to read them.

Franklin became a leader in the fight against English domination of North America. He travelled many times to London to represent the rights of the poorer North American settlers.

Finally, the break with the English rulers came in 1776. North America



Everybody wanted to read the pamphlets Ben wrote and published.

declared itself independent from England. This was proclaimed in the Declaration of Independence. One of the signatures of this famous document is that of Benjamin Franklin.

Can you find his signature in the copy of part of the document shown below?

Done on Convention by the unanimous Consent of the States present the Seventeenth Day of September in the Year of our Lord one thousand seven hundred and Seventy seven and of the Independence of the United States of America the Twelfth In witness whereof We have hereunto subscribed our Names.

Delaware { *George Read*
Thomas Mifflin
Richard Bassett
James Wilson

Maryland { *Samuel Chase*
Dan of St. Thomas
John Blair
James Mason

Virginia { *George Washington*
Patrick Henry
Richard Lee
James Madison

North Carolina { *William Hooper*
John Motte
Charles Cotesworth Pinckney

New Hampshire { *John Langdon*
Nicholas Paine

Massachusetts { *Samuel Adams*
John Hancock
James Otis
Samuel Johnson

Connecticut { *Roger Sherman*
Micaiah Hunkins
Wm. Livingston

New York { *David Brearley*
John Jay
John Jay
John Jay

Pennsylvania { *Benjamin Franklin*
Thomas Mifflin
Robert Morris

(Philadelphia)



*Independence Hall,
Philadelphia, USA,
where the
Declaration of
Independence was
adopted.*

Franklin's grave and the hall where the Declaration of Independence was adopted, are tourist sights in Philadelphia today.

Independence Hall (as it is now called) has been carefully restored and looks today exactly as it did the day the Declaration was adopted.

Curtains via the navy

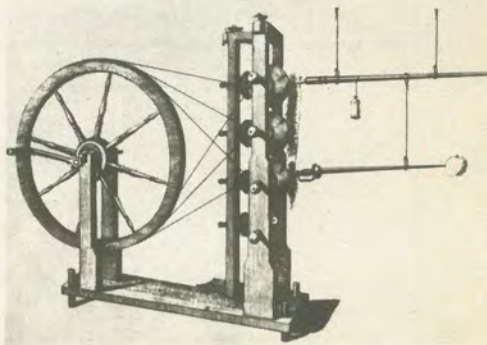
When the building was being restored old bills (accounts) were consulted. It was found that the curtain material used in 1776 was still being woven in England (for the Royal Navy). So even the curtains are of the same kind of material as the ones Franklin saw the day he helped to create the United States of America.

In the same square as Independence Hall stands Philosophy Hall, which housed the American Philosophical Society* founded by Franklin. In spite of his work as a printer and his political activities Franklin found time to do scientific experiments. It was still possible two hundred years ago for a gifted amateur to make important discoveries in physics without having research resources at his disposal.

Machines which rubbed and stroked

Electric attractions and repulsions similar to the ones which you have tested had been known for many years before Franklin's time. Machines had been invented to do the rubbing and stroking mechanically and so bigger charges could be collected and longer sparks crackled and flashed with bluish fire.

Things were said to have the 'electric virtue' which sometimes could be passed to other objects.



* Natural philosophy was the old name for the scientific study of the universe.

During the first half of the eighteenth century people were very excited about the spectacular demonstrations of this modern 'miracle' and could not see enough of it. A few universities started to give lectures on the new science (around 1740). The students complained bitterly when they could not get into the lecture rooms because the rooms were crammed with outsiders who wanted to watch what was going on.

You can hardly blame the people in the students' lecture rooms. Demonstrations were intentionally made very thrilling.

Shock from a kiss

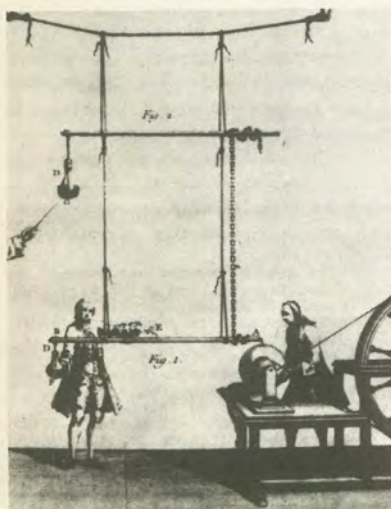
For instance, in one demonstration a pretty girl stood on an insulating stand. She held on to an electrical charging machine. As the charging went on, her long hair spread out and the ribbons of her dress stood out horizontally.



People who were watching were asked to hold the girl's hand or give her a kiss. If they did, they immediately got a shock. This was great fun for everybody except the ones who got the shocks.

Once Franklin was in the audience of such a show. To him this charging was something worth looking into. He wrote to one of his many London friends and asked for one of the special glass rods necessary for charging, as well as other bits of equipment. The very dry, cold winters in Philadelphia were just right for experiments with charges.

Franklin had many bright ideas and he tried them all out. The one which made him famous came from the results of experiments



Mechanical devices used in Franklin's time for producing charges.





with pointed metal rods 'both in drawing off and in throwing off electric fire,' he wrote to a friend.

Until Franklin's time people thought that thunder and lightning were explosions in gases.

Galoshes and a fur coat

During one bitterly cold winter, Franklin, noticed that the little sparks which he got when he rubbed his dry galoshes against his fur coat looked very much like mini-lightning.

Maybe lightning was just a spark? He set out to find proof for this notion. He flew a kite right into a thundercloud. He described what happened in great detail in a famous letter to a friend.

When writing about the kite, which he made from a large silk handkerchief, Franklin said: '... the corners tied to a cross made from two light strips of cedar, to the top of the upright stick of the cross is to be fixed a very sharp pointed wire, rising a foot or more above the wood. To the twine, next to the hand, is to be tied a silk ribbon and where the silk and twine join, a key may be fastened—the person who holds the string must stand under some cover, so that the silk ribbon may not be wet.

'... As soon as any of the thunder clouds came over the kite, the pointed wire will draw the electric fire from them, and the

kite, with all the twine will be electrified, and the loose filaments of the twine will stand out everyway, and be attracted by an approaching finger.

'... And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle... and from the electric fire thus obtained, spirits may be kindled [i.e. the spark ignites alcohol vapour] and all the other experiments be performed, which are usually done by help of a rubbed glass tube, and thereby the sameness of the electric matter with that of lightning completely demonstrated.'

(This extract is from a letter written in 1752.)



As long as Franklin held the dry, silk ribbon he could fly his kite fairly safely, but the sparks drawn from the key were sometimes huge and he got severe electric shocks.

The information in the letter was passed on and others repeated his experiments with variations.

One professor went close to his apparatus just as a thunderstorm was coming and *'a globe of blue fire, as big as his fist, jumped from the apparatus towards the head of the professor . . . The professor was killed immediately . . .'*

So don't you dare to try experiments like Franklin's.

In another letter Franklin mentioned more of his work: *'I erected an iron rod to draw the lightning down into my house in order to make some experiments on it, with two bells to give notice when the rod should be electrify'd—I have given orders in the family that if the bells rang when I was away from home, they should catch some of the lightning for me in electric phials.'*

The electric phials were probably Leyden jars. Did you try to make a Leyden jar? (See page 38.)

Can you imagine the scene in the household? The bells ring and everybody rushes to connect up wires so that Father can play with 'electric fire' when he comes home.

The pointed iron rod became known as a lightning conductor. It made Franklin world famous. The rod decreased the danger of lightning setting a building on fire. If lightning did strike, charges were conducted harmlessly to the ground instead of setting a building on fire.

Protecting a cathedral

St Paul's Cathedral in London, which towered over the surrounding buildings, needed protection from lightning. Could there have been a better person than



The Franklin family rush upstairs to 'catch the lightning' for Father.

Franklin to head a committee to design a lightning conductor for the cathedral? This was 1769 when he was still in favour with the authorities.

Later, after the Declaration of Independence (1776), Franklin was hated by the British as a rebel and rebels cannot be trusted. This caused King George III to declare that blunt rods not pointed ones were the right thing. He had just lost thirteen valuable colonies and he ordered all the pointed rods on his palace to be replaced by blunt ones for they would **push** the lightning **back**.

From your experience, which is better? How would you settle the argument about the pointed and blunt rods?

Franklin invented a useful model to explain charging and charges. According to his model all unelectrified bodies contain a normal amount of an electric fluid. Charging involves either an increase or a decrease in the amount of electric fluid present.

Positive and negative

If a body contained more than its normal share of fluid, Franklin called it **positive** and identified this charge with that found on glass rubbed with silk.

If a body had less than its normal share, it was said to be **negative**.

Franklin further assumed that rubbing glass with silk pulled fluid from the silk and acquired (in his words) '*a positive charge, leaving the silk negatively charged by an equal amount*'.



Today we know that electric charge is carried by particles. Tiny, negatively charged particles, called electrons, are responsible for the charge and conduction of charge in metals. So, Franklin's 'fluid' could be considered a stream of electrons moving from the glass to the silk.

After the Declaration of Independence came the War of Independence. The American 'rebels' were poorly equipped to fight the British army, and, if the newly formed United States was to remain independent, help was needed urgently.

The only possible ally was France and Franklin was sent to France to negotiate.

Franklin was still a printer, a public servant and a leader as well as continuing with his science experiments.

Mission to France

Life for the people at the top in the big cities of France was very different from life in Philadelphia.

A small alley built in Franklin's lifetime is still standing in Philadelphia. The modest little houses, some of them still inhabited, show what life must have been like in that colonial city.

These little houses must have been in startling contrast to the luxury of aristocratic Paris and the nearby town of Versailles, where Franklin was sent to obtain support for the new, struggling United States.

The voyage across the Atlantic was full of dangers too. Franklin carried with him a letter from the new government of his country—the first American Government. The letter was a plea that he should be set free if captured by an English ship because he was a man of science and his services to his fellow men should be respected even in wartime.

However, Franklin arrived safely and managed to get supplies of arms and uniforms. Several French officers were so impressed by his pleas that they sailed across the Atlantic to join the rebel American army.

Franklin's fame as 'the man who had tamed the lightning' had preceded him to France and while he was there large crowds gathered to gaze at the celebrity.

At the French Court

He realized that he could not compete with the extravagant elegance, the silks, laces and velvets of the French courtiers and so he shrewdly decided to stay in a simple homespun, brown woollen suit. He did not wear an elegant curly wig, as the courtiers did, but instead he wore a big fur cap which protected his balding head.

This is how the French saw him—an old man (he was then seventy years old) from backward America; a wise man who, in his simple way, could find the answers to many problems.

The French adored Franklin. He was cheered and admired everywhere. He became fashionable. Well groomed ladies had to have a hair-do *a la Franklin*—a tall structure imitating his fur hat.

Have you seen pictures of Queen Marie Antoinette and her ladies? They wore jewels and all sorts of ornaments on their towering hair-dos. It became the fashion to wear a little statue of 'dear Benjamin' nestling in one's hair.

He was so marvellous, this revolutionary from across the Atlantic! These aristocratic ladies of the court had no idea that their time was running out. The terror of the French Revolution was only a few years away. Their elegant heads were soon to roll under the guillotine.

Franklin returned to America in 1786, only three years before the outbreak of the French Revolution.



Electrostatics

His work in science was carried on by many scientists who followed him. For a long time charging and the study of charges, called 'electrostatics', was regarded as interesting but not important in a practical way.

It is only during the past thirty years or so that many uses have been found for charges. We now use electrostatic smoke removal and spray painting, as well as electrostatic particle accelerators to name only a few.

One of the latest advances, based on electrostatics, is a process for copying. Appropriately, the first public demonstration of this process was the copying of a line-drawing by Benjamin Franklin.

LUIGI GALVANI AND THE FROGS' LEGS



The electrifying accounts about Benjamin Franklin's findings on charges spread quickly: mainly by letters carried on horseback.

The news could not travel as fast as it does now because all means of rapid communication—from telegraph to satellite—depend on electric current in some way. At that time nobody knew how to make continuous current.

Electricity was fashionable. Nobody could call himself a scientist if he didn't experiment with this new discovery. Of course it was much easier then to keep track of what was going on in science.

In Bologna

One of the other scientists experimenting with electricity at about the same time as Franklin was Luigi Galvani (1737–98). Galvani was a professor of anatomy, and lived and worked in Bologna, a beautiful city in northern Italy.

This Italian scientist decided that the muscles of frogs' legs might be an interesting topic to study. After all, frogs were such excellent jumpers. How did they do it?

He dissected (cut open) the legs of dead frogs to expose the leg muscles.

Like many others in the scientific world he had an electricity machine. He used it to confirm what others had found before him, that muscles twitch when they touch a highly charged object.

Lightning and the twitches

Franklin had shown the world that lightning was due to a big charge. Galvani knew about Franklin's discovery and decided to find out whether lightning also produced these peculiar twitches in frogs' legs.

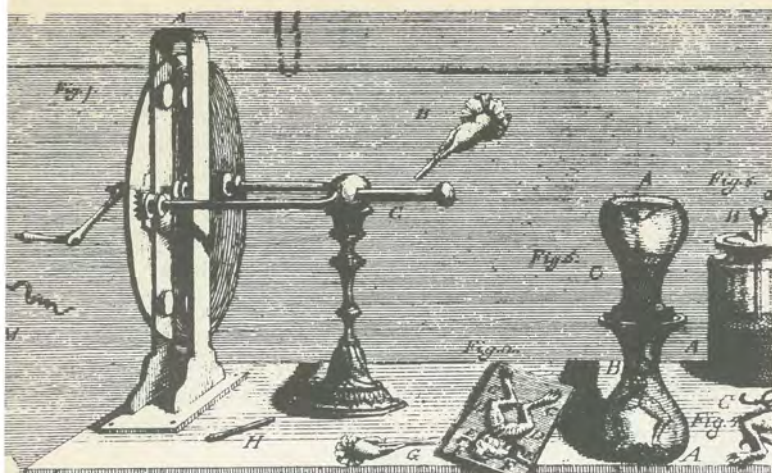
You cannot get thunderstorms for experiments just when you want them, but you can get ready for them. Galvani left the legs attached to a brass hook hanging from the iron railings of his balcony. The legs twitched occasionally, but both in thunderstorms and in fine weather, so there was no definite connection with the weather.

Galvani was not happy with the legs twitching in all weathers. He wanted a clear answer to his problem. One day he became very impatient and pushed the brass hook against a railing so that the legs touched both the hook and the railing at the same time. The legs twitched. They did so every time he pushed. Apparently it was necessary for the two different metals to touch each other **and the legs at the same time**. He tested this in his laboratory, which was also the family sitting-room. He found that when two different metals touched each other and the legs all at the same time, the legs twitched.

Was it Galvani or his wife?

One other account of the balcony scene claims that Lucia Galvani, his wife, who knew a great deal about science, made the first observation.

There are other stories about the balcony scene and it is difficult to decide which one is correct.



Equipment used by Galvani in his work on 'animal electricity'.

Galvani designed a series of experiments which showed that muscles (or nerves) and two different metals all touching produce jerks.

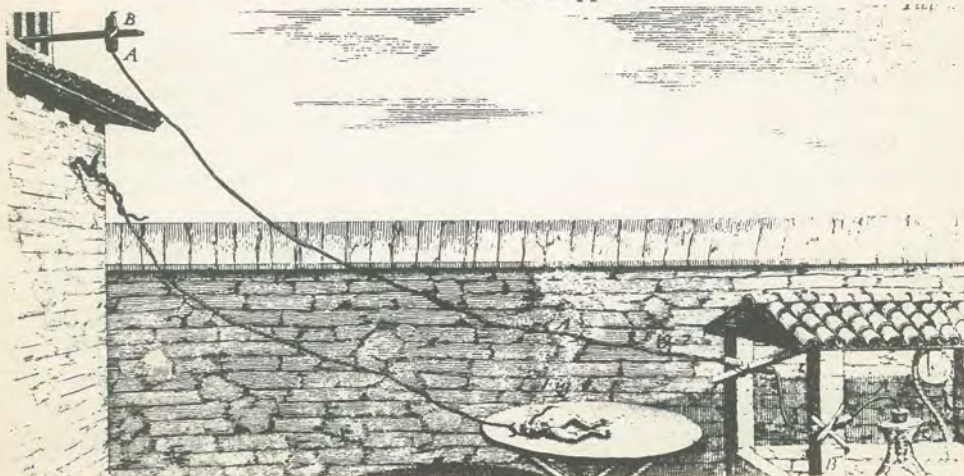
He invented a model to account for it. He said: '*Animal bodies are in some ways storehouses of electricity and this electricity is discharged by contact with metals*'. There was something mysterious which he called 'animal electricity'.

His model was supported by the fact that there are electric eels and that some fish can give you a shock when you touch them. Today we know that the animal had nothing to do with it.

Galvani published this theory (model) and 'animal electricity' became known as galvanism.

His discoveries and fantasies appealed to the public to such an extent that even now, nearly two hundred years later we use phrases such as 'galvanize into action'. There is a special kind of current detector, the galvanometer, which is named after this former professor of anatomy at Bologna.

When something as intriguingly new as 'animal electricity' turns up, scientists want to try it out for themselves. Among Galvani's fellow workers was Alessandro Volta, a man who later became his chief opponent.



VOLTA, THE ARISTOCRATIC SCIENTIST



Alessandro Volta's life (1745–1827) was very different from Benjamin Franklin's. Volta was the son of an aristocratic family in Como, northern Italy, and was able to go to a good school. French was the subject he liked best and he learned to speak the language fluently.

At this time France was one of the main centres of scientific discovery, and Volta was able to read about the scientific developments across the border. He could write letters in French and explain his own work convincingly to people in France.

The electrophorus

Through reading and teaching Volta became very interested in electricity. He invented the electrophorus (see page 36). His work was recognized and he was made first a professor and later the rector (the head) of the University of Pavia, northern Italy.

Unlike Franklin, who could give only his spare time to his experiments, Volta could

give most of his time to his own tests. What is more, being at a university in a particularly cultured part of the world, he met many people with whom he could discuss his ideas.

The printer and public servant, Franklin, had hardly anybody to talk with in distant America. He had to rely on letters (which took a long time to cross the Atlantic) to communicate his ideas to people in other countries.

Everybody in science talked about animal electricity in those days and Volta repeated some of Galvani's experiments and even tested himself!

Want to try the tongue test?

He put a piece of tin foil on top of his tongue and a silver coin underneath and connected them with copper wire. Suddenly there was a sour taste in his mouth. He also had animal electricity. *(Have you? Find out for yourself in the way Volta did.)*



In spite of his own experience Volta started to suspect the model of galvanism. It was fairly easily checked. If he could get similar results with non-living things, then obviously animals had nothing to do with the appearance of currents.

Volta's experiments were similar to the activities which you may have done when you made electric cells consisting of two different metals and a conducting liquid. Of course Volta could not use a globe as a detector as globes weren't invented until about one hundred years later. Volta used

he few means available like sparks and an instrument called 'the gold-leaf electroscope' to detect charges.

In a letter to the President of the Royal Society*, Sir Joseph Banks, Volta described an electric cell he had made: '... Yes! the apparatus of which I speak, and which will doubtless astonish you, is only an assemblage of good conductors of different sorts arranged in a certain way. 30, 40, 60 pieces or more of copper, or better of silver, each in contact with a piece of tin, or what is much better, of zinc and an equal number of layers of . . . pieces of cardboard—well soaked in salt-water . . .'

This apparatus has become known as the voltaic pile. It was the first battery of cells.

Volta found that a spark jumped when he touched a wire to the first silver disc and brought the other end of the wire close to the last zinc disc.

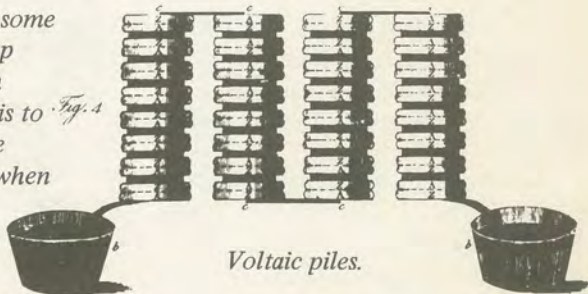
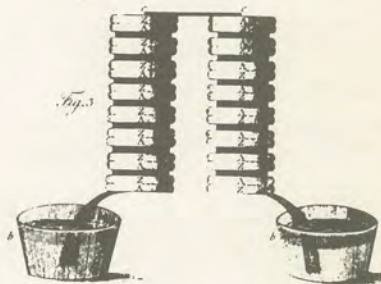
How to make a voltaic pile

You could try to build a pile for yourself. You can try it using coins. Volta told how to do it in another part of his letter:

'I further provided a sufficiently large round plates (for example coins) an inch in diameter more or less . . . all that is necessary is that they may be arranged easily one above the other in a column.'

I further provided a sufficiently large number of discs of cardboard . . . or of some other spongy material which can take up and retain . . . much salt-water in which they must be soaked if the experiment is to succeed. These pieces . . . I make a little smaller than the metallic discs, so that when placed between them . . . they do not

protude . . . [and] I wiped them so that the liquid does not come out in drops, I place horizontally on a table one of the metallic plates, for example, one of the silver ones, and on this first plate I place a second plate of zinc, on this second plate I lay one of the moist discs; then another plate of silver followed immediately by another of zinc, on which I placed again a moistened disc—I continue—to form several of these steps a column as high as can hold itself without falling.'



*The Royal Society was founded by Charles II to serve as a rallying point for all scientific discoveries and theories. To become a Fellow (F.R.S.) was a great honour and it still is 300 years later. Sir Joseph Banks was the famous botanist who sailed in the Endeavour with Captain Cook. Sir Joseph drew and described many Australian plants.



Volta's 'crown of cups'

'Crown of cups'

Volta experimented with many other combinations, one of which became known as the 'crown of cups'. This 'crown' began as a number of glass vessels containing salt-water or dilute sulphuric acid with a copper and zinc plate in each. Volta then joined the 'cups' in series, that is, the first zinc to the second copper and so on. He was delighted that he got quite a shock when he joined the first copper plate to the last zinc plate.

He was intrigued that a current existed all round the circuit. He is quoted as saying: *'This perpetual motion of the electric fluid may seem paradoxical and may prove inexplicable, but it is none the less real and we can, so to speak, touch and handle it.'*

These experiments, which produced continuous electric currents for the first time, became widely known. Did you realize that the electric current had been known for less than two hundred years?

A whole, new world opened up with the discovery of continuous electric currents.

Invitation from Napoleon

The letter which gave the instructions about the 'crown of cups' was written in March 1800 and Volta was invited everywhere to demonstrate the crown of cups, and the voltaic pile.

During the French Revolution (1789–99) the revolutionaries were science minded, e.g. the metric system originated then. This interest in science persisted after the revolution was over and Napoleon had become the ruler of France—first as First Consul and later (1804) as Emperor.

While he was still First Consul Napoleon invited Volta to Paris.

Napoleon wanted to watch the demonstrations. He had some fantastic notions, very different from our present ideas, and is reported to have said: *'What are electricity, galvanism and magnetism? In there lies the great secret of nature. I am inclined to believe that man is the product of these fluids.'*

He offered a prize of 60 000 francs (a very big sum then) to *'the one who, by his experiments and discoveries in galvanism and electricity [note the distinction that was made in those days] will make a step forward comparable to that made in these sciences by Franklin and Volta.'*

The first winner of this award was the great British chemist Sir Humphry Davy who applied the new electric current to molten sodium hydroxide and potassium hydroxide



and was the first man to see the unusual metals sodium and potassium.

Davy made many discoveries but, in his own words, his greatest discovery was a young man called Michael Faraday. Faraday* made many discoveries that you will often hear and read about.

Volta received France's highest award, the Legion of Honour, and many medals and other decorations for his services to science. He was even made a count.

Setting up electric cells took a long time and was a complicated business. In spite of this, they were used extensively and startling discoveries were made. Many things which students learn about electricity in schools nowadays were discovered within the first twenty years of the discovery of electric current. These things include heating up of wires by an electric current, the chemical effects that you have studied and the magnetic effects.

During the last part of the nineteenth century other sources of electrical energy called 'dynamo-electric generators', or 'generators' were built. These generators were based on a different principle. From then on cells remained in use only where portable sources of electricity were required, such as in torches and in portable radio sets.

The expensive cells

It is more expensive to use dry cells than to use electricity outlets partly because zinc, which is used up in the process, is an expensive metal.

The other, still widely used cell is the lead storage cell. This is used mainly in car batteries.

In the infancy of the motor car, 'electric cars' were made, with lead storage cells providing the power.

These cars had two serious disadvantages:

- the large lead plates which were needed were far too heavy and
- the cars could not go very far before they had to go in to a garage for re-charging.



*One of the subjects which Faraday investigated thoroughly was the passage of electric current through solutions, especially solutions of metal salts. He wanted to find out how much copper was deposited in a given time by a given current. The results of Faraday's careful measurements opened up new fields to explore.

A new type of cell

A new cell is being investigated at present. It is called the fuel-cell, and it uses oxygen from the air and hydrogen. So far it cannot be used to drive motor cars. If the problems were solved the fuel-cell could be used for cars, and air pollution from exhaust fumes would be reduced.

- Next time you switch on your torch, think of Galvani and the frogs' legs. Without the legs you would have no light, even though there is no 'animal electricity' inside the torch.
- You will recognize in the words 'volt' and 'voltage' that we will always remember Alessandro Volta too.
- Whenever you see the lightning 'spark'—think of Benjamin Franklin.

Enfield 8000 electric car driven by four 12 volt batteries. A built-in charger allows it to be plugged into a mains electricity supply for recharging. Top speed 65 kilometres per hour. Range 150 kilometres.



(Photo by courtesy of the State Electricity Commission of Victoria.)

BOOKS TO READ

Our lives are made easier by electricity.

Many scientists other than Franklin, Galvani and Volta, had a share of the work of discovery. You may like to find out about some of them. You already know a little about two more—Davy and Faraday.

There are many books to read. Some which may be useful are:
Nuffield Foundation. *The Discovery of the Electric Current*. London, Longmans, 1965. (Chemistry Background Books)
Ronan, C. (comp.) *Faraday and Electricity*. London, Jackdaw, no. S5.
Sutcliffe, A. and Sutcliffe, A.P.N. *Stories from Science: 2* (chapters 33, 34 and 35). London, Cambridge University Press, 1962.

TEST YOURSELF—WHODUNIT?

Answer the following questions in your notebook.

- 1 Franklin, Galvani and Volta lived and worked at about the same time as
 - A Columbus discovered America.
 - B Captain Cook explored Australian waters.
 - C Edison invented the electric light globe.
 - D the first artificial satellite was launched.
- 2 When Galvani touched a frog's leg with two different metals he saw the leg twitch, suggesting that electricity was present. He explained this by saying that frogs have a store of 'animal electricity' in them, and this electricity is released by contact with metals. For which **one** of the following reasons would Galvani's explanation have to be **rejected**?
 - A Two different metals and a conducting liquid can produce electricity whether they are inside or outside the body of an animal.
 - B Animals' legs can twitch even when they are not touched by two metals.
 - C Galvani was only guessing; electrical effects could not be explained until after the electron was discovered.
 - D Experimenters before Galvani had already discovered that electricity from outside the body of the animal made its muscles twitch.
- 3 List **three** ways in which science today differs from science as practised in the time of Franklin.
- 4 List **three** important ways in which the use of electricity has changed people's lives.

Now turn to Check Your Answers on page 108.

Check Your Answers

No one can guess exactly what will happen as a result of any one activity in Charge! If you have a result which is different from the one suggested here don't worry about it being different—just try to find out why. You will gain more doing this than by repeating the activity and trying to make your result the same as the one here.

CHARGING

- 1 The charged tester would have been attracted to your hand. In fact, to prevent the tester touching your hand, you would have had to move your hand. The charged tester then probably followed your hand.
- 2 It is most likely that your hand didn't attract bits. It is uncharged.
- 3 All uncharged things probably attracted the charged tester.
- 4 The charged A tester was probably repelled (pushed away) by the charged strip A.
- 5 The charged A tester was probably attracted to the charged strip B.
- 6 The charged B tester was probably attracted by the charged strip A and repelled by the charged strip B. If your results are not different from those of questions 4 and 5 use a new piece of plastic on your tester and repeat the investigation.

The tester strip is made of the same material as the strips A and B. It is reasonable to suggest that when rubbed with the cotton it has the same type of charge as the charged strip A. When rubbed with nylon it has the same type of charge as the charged strip B. The same types of charge are often called **like** charges.

- 7 The tape probably attracted the tester.
- 8 The plastic probably worked in the opposite way to the tape. It repelled the tester.

Questions 7 and 8 suggest that two types of charge were produced at the same time—one type on the tape, the other on the plastic.

- 9 You probably found that your charged strip A repelled the charged tester and the cotton material attracted it. On the other hand your charged strip B probably attracted the charged tester and the nylon material repelled it.
- 10 The lamp does not glow continuously. It flashes just once. You may have missed it. If so, repeat the activity and look carefully at the lamp.
- 11 The lamp may flash again when placed on other parts of the charged strip.
- 12 The same thing probably happened for the charged strip B. The lamp glowed once when it touched a spot on the charged strip.
- 13 The sum of the positive charges is +13. The sum of the negative charges is -9. The strip is positively charged by the extra 4 positive charges.

TEST YOURSELF—CHARGING

- 1 C No. A spark can jump when two highly charged objects with unlike charges are near each other. Strong attraction between the tiny charges causes them to be ripped off and fly through the air from cloud to cloud or from cloud to Earth. The air becomes hot and expands and so thunder booms. The vibration of the thunder is a **result** of the giant spark, not the **cause** of it.
- 2 A, C Objects which are uncharged attract objects carrying a charge. Objects carrying unlike charges attract each other.
- 3 B Objects carrying like charges repel each other. What is more, repulsion occurs only when the objects are charged, and carry like charges—not in any other conditions. So if two objects repel each other, it is a sure indication that they are both charged.
- 4 D If two objects neither attract nor repel each other then they are both uncharged.
- 5 D Whenever an object is charged by another, both objects become charged. One object becomes positively charged and the other negatively charged. If, say, the adhesive tape pulled some negative charges away from the plastic strip, the tape would have more negative charges than positive charges, and so would be negatively charged. By similar reasoning the plastic strip would be positively charged.
- 6 D You cannot tell whether the strip will become positively or negatively charged unless you know the type of material from which the drip-dry shirt is made. Remember that different types of material may produce either a positive or negative charge on the plastic strip.
- 7 C
 - A All three balloons are positively charged — like charges repel each other.
 - B The grey and white balloons are positively charged — like charges repel each other.
 - D The grey and white balloons are uncharged — uncharged objects neither attract nor repel each other.
 - E The grey and blue balloons are positively charged — like charges repel each other.
- 8 C Positively charged objects contain both positive and negative charges. If an object had an equal number of negative and positive charges it would be uncharged. A positively charged object has an excess of positive charges.
- 9 B If you cannot agree with this answer refer to How Does Charging Occur? page 16 and Explanations About Charging, page 18 for details.
- 10 A A scientific model is an idea which scientists use to help them explain something. Because the idea may change as more information is gathered, scientists would not claim that a model gives a **true** description of nature.

OPTION 1: HOW DO CHARGED OBJECTS BEHAVE?

- 1.1 Poly was probably attracted to the strip, touched it, rolled around on it and was finally repelled.
- 1.2 The charged strip probably repelled Poly. Since only like charges repel, (see page 11) Poly must have the same kind of charge as the strip A. Positive charge.
- 1.3 Poly was probably repelled.
- 1.4 Since only like charges repel, charges from the charged strip A must have moved along the metal rod to Poly. As a result Poly was pushed away.
- 1.5 Poly probably did not move. A clean plastic strip does not let charges move along it.
- 1.6 Metals and carbon will conduct charge.
- 1.7 You probably saw a spark or heard a soft 'crack' as a spark jumped. If not, try again. Sometimes this works well, but at other times you may not succeed.
- 1.8 Charges do not move on plastic. You have found this out before.
- 1.9 The moist strip should conduct.
- 1.10 The greasy strip should also conduct.

TEST YOURSELF—OPTION 1

1 A

- B Although clean plastic is a good insulator dirty plastic can conduct charge quite well.
- C Metals are very good electrical conductors.
- D Not likely! How could you ever get an electric shock, if the human body weren't a conductor?

2 A They are all in fact made of metals which are good conductors.

- B L must be charged since L and R repel. Therefore, L must have conducted some charge away from R.
- C,D How does the charge get down to L unless P and R conduct it?

3 A

- B You've got things back to front. It is like charges that repel.
- C What happens when you bring two uncharged objects close together, such as when you bring your finger near a tiny piece of paper?
- D A charged object like R would attract L if L were uncharged.
- E If R were uncharged it would attract a charged object like L.

- 4 **B** To prevent the static electricity from building up, something is needed to conduct the charge away. Metal is a good conductor so metal strips in the soles of the shoes should do the job.
- A It could possibly be made to work but it would be expensive and clumsy.
 - C In general, electric charge would build up only when you are wearing shoes with insulating soles.
 - D Any charge given to the shoes would not stay on them for very long.
- 5 Records are made of plastic which is a good insulator. They can be charged easily and are hard to discharge. Once a record is charged it will attract small particles—dust, for example. Wiping the record with a clean cloth usually charges the record.
- To keep your records clean you can use a conducting liquid on the cloth to prevent electric charge from building up. One quite good liquid is clean water. Manufacturers sell a number of special antistatic liquids which can also be used.
- 6 **B** Some animals, like electric eels, can give shocks. They do have a store of 'animal electricity'. Humans and most other animals do not have this store, although electrical activity goes on in their bodies. However, this is not responsible for the sparking.
- Your school library may have more information about these. Electricity in animals was first investigated a long time ago. You can read about it in Option 6.
- 7 **D** Sometimes electric charge is deliberately used in spray-painting. The object to be painted is earthed and attracts tiny charged drops of paint from an atomizer. But spray-painting is not used to prevent or get rid of unwanted electric charge.
- B The men collecting the toll often received electric shocks when they touched the cars. So metal wires were installed in the road to discharge the cars before they reached the men. Now automatic toll collectors are used instead of people and the wires have been removed.
- 8 Photo 1
- 9 Photo 1
- 10 Photo 3
- 11 Photo 2
- 12 Photo 3

OPTION 2: WHAT IS BLUE?

- 2.1 The solution probably turned deep green at first and then blue. A brown, smelly gas probably bubbled up. Nitric acid changed pinkish brown copper metal into a new, blue substance.
- 2.2 Bubbles probably appeared alongside the copper strip attached to the negative terminal of the power-pack. If you looked just below the copper strip attached to the positive terminal, you would have seen 'blue streaks' moving towards the other (negative) copper strip. If you didn't see the streaks, try placing white paper behind the vial.
- 2.3 Using the other vial you could start again with a colourless acid solution and connect the strips to the opposite terminals of the power-pack.
- 2.4 Dilute sulphuric acid does not act on copper. An electric current is necessary to produce a reaction.
- 2.5 The crystals probably looked like copper sulphate crystals.
- 2.6 Both the charged strips A and B most likely attracted the copper sulphate crystals.
- 2.7 Since the crystals were attracted by positively and by negatively charged strips, they must be uncharged (see page 11).

TEST YOURSELF—OPTION 2

- 1 A An atom is uncharged before it loses an electron. Electrons are negative. So after losing an electron the atom becomes positive and is called a positive ion.
- 2 B
A, C, D You have missed one of the main points of this option.
Read page 48 again.
- 3 D No current would flow unless you used a solution of copper sulphate. You have not been told why but you might be interested to find out.
A, B, C Set up the circuit and see for yourself. Then perhaps you would like to find out **why** it does not work.
- 4 C The uncharged crystals would be attracted to both charged strips.
A, B, D Both strips would attract the crystals, but if you were to try this out, the strips may not appear to attract them because the charge on each strip may be too small.

5 A

B, C Atoms are always uncharged (see page 49).

6 B The electron is negative. Together with the metal ion it makes up the uncharged atom. So the metal ion must be positive.

7 D Scientists can never be sure of giving a **true** description of nature. They always have to be prepared to change their description if new observations are made which do not fit in with their present ideas.

OPTION 3: PUTTING ON A SHINY COAT

3.1 Even though you may have noticed bubbles on it while the current was turned on, the carbon rod connected to the positive terminal probably looked unchanged.

3.2 The carbon rod connected to the negative terminal probably had a pinkish brown coating on it.

3.3 You probably noticed brown fumes coming from the rod. This is what happens if concentrated nitric acid comes in contact with copper. Thus the coating must have been copper. 'What about the reaction of nitric acid with the carbon rod?' you say. Nitric acid doesn't react with carbon. Try it yourself with the other carbon rod.

3.4 You could place a clean carbon rod into copper sulphate solution and leave it there for five to ten minutes.

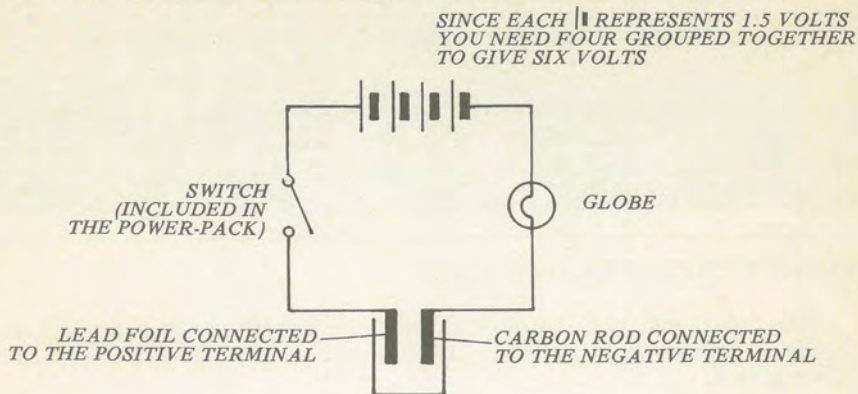
3.5 The coated rod probably lost its coating, and the other carbon rod probably became coated with copper.

3.6 Put your suggestions into your notebook.

3.7 You probably noticed that the carbon rod attached to the negative terminal had a thick powdery coating of copper on it. Some of this copper may have fallen off into the solution. Also, the carbon rod attached to the positive terminal may have appeared to be damaged. Powdery carbon from this, along with the copper, probably made the solution appear dirty. (If so, you could filter the solution, and look at it. The blue copper colour will have probably nearly disappeared. This suggests that the copper came out of the solution and was deposited on the negative electrode.)

Option 3 continued next page

3.8 Your circuit diagram should look like this.



- 3.9 The positive electrode may have become smaller. During electroplating, a metal deposit is formed on the negative electrode. This metal deposit comes from the solution (see answer to question 3.7). Metal from the positive electrode replaces this. Hence the positive electrode gradually disappears.
- 3.10 You probably noticed shiny, silvery crystals being deposited on the carbon electrode. If you didn't, leave the current on for longer as suggested in question 3.11.
- 3.11 You probably saw shiny lead crystals looking like small feathers build up on the negative electrode and spread across the solution towards the positive electrode. (See the photo on page 58.)
- 3.12 You probably saw bubbles coming off from both the magnesium and carbon electrodes. The solution may have become 'milky'.
- 3.13 The carbon electrode probably looked unchanged. The magnesium was probably slightly eaten away. A reaction definitely occurred, but no magnesium appeared on the negative carbon electrode.
- 3.14 You may have seen a 'sticky' coating forming on the magnesium and/or a white substance floating in the magnesium sulphate solution, or settling to the bottom of the vial. Nothing however, appeared on the carbon electrode.
- 3.15 You would need silver for the positive electrode and a solution of a silver compound.

TEST YOURSELF—OPTION 3

Did you get a coating on the nail? If so, it was probably not very shiny. The conditions have to be very carefully controlled to get a satisfactory coat. Special preparation of the electrodes has to be done before the electroplating begins. Even after the coat has been put on, polishing is necessary to make it shiny.

What must be done to make sure that the coating on the nail is nickel, and not copper or lead or some other metal? A solution which contains nickel ions and no other metal ions has to be used. Any of the three arrangements below would produce a nickel coat.

1 A positive electrode of nickel in a dilute acid

With the electrical energy from the cell, nickel atoms from the positive electrode become nickel ions in the solution. The ions in solution become nickel atoms on the nail, which is the negative electrode. This arrangement would have made a slow start because it takes some time for the nickel ions to build up in the solution.

2 A positive electrode of carbon in a solution of a nickel compound (e.g. nickel sulphate)

This would have started well with plenty of nickel ions in the solution. As the ions became changed into atoms on the nail, the plating would slow down and eventually stop.

3 A positive electrode of nickel in a solution of a nickel compound

Nickel ions in the solution are deposited on to the nail as soon as the current is switched on. Atoms from the nickel electrode are changed into ions and replace those which are taken out of the solution. This arrangement appears to be the best one.

How successful were you in your attempt to nickel-plate a nail? If you were not successful at all, or only after getting help, you could try again. But first re-read the activities in the option to make sure you know what to do.

OPTION 4: ELECTRIC CELLS

- 4.1 Probably the solution bubbled fiercely and changed colour. Copper was deposited on the can and some magnesium was used up. The can probably felt warmer than before. The globe lit.
- 4.2 The cell probably restarted.
- 4.3 Scraping the deposit from the can, cleaning the magnesium and replacing the solution with fresh copper sulphate or chloride are possible ways of restarting the cell.
- 4.4 The globe probably lit up. There were probably bubbles around the copper plate and possibly the zinc plate as well.
- 4.5 In this case, both electrodes are made of the same material—lead.
- 4.6 The solution probably bubbled so much that you couldn't see what was happening to the electrodes.
- 4.7 The plate probably became coated with a brown powder.
- 4.8 The plate probably showed no change.
- 4.9 The liquid possibly appeared 'milky'.
- 4.10 The globe probably lit up, but only for a very short time.

TEST YOURSELF—OPTION 4

- 1 **A** A cell is a combination of two different conducting plates, e.g. two plates made of different metals, in a conducting liquid. The combination can supply an electric current. In the storage cell which you made, although you started with two electrodes of the same metal, the cell wouldn't 'work' until it had been charged, and in this process the lead of the positive electrode was changed into another substance.
 - B** The two plates are made of the same metal.
 - C** The two plates are made of the same metal.
 - D** There is only one metal plate.
- 2 **C** All of the energy which has been fed into the storage cell can never be fully recovered as electrical energy. Some of the stored chemical energy is transformed into other forms of energy (e.g. heat).
- 3 **B**
 - A** This is an example of movement energy being changed into electrical energy.
 - C** This is an example of electrical energy being changed into chemical energy.
 - D** This is an example of electrical energy being changed into heat energy.

- 4 Here are some differences between a car battery and a torch 'battery':
- 1 A car battery is a storage battery which can be recharged when it runs down. A torch 'battery' however cannot be recharged; it must be replaced.
 - 2 A car battery contains a series of cells joined together; a torch 'battery' is usually a single cell. (See page 67 for information on a torch 'battery'.)
 - 3 A car battery is heavier and larger than a torch 'battery'. It has lead plates for electrodes.
 - 4 In a car battery the electrodes are in a liquid, usually acid. In a torch 'battery' the liquid is replaced by a paste. This is why torch 'batteries' are called 'dry' cells. (See page 67 for information about 'dry' cells.)

You may have thought of other differences. Discuss them with another student or a teacher.

OPTION 5: WILL ANY LIQUID DO?

- 5.1 You probably noticed a wide variation in the liquids tested. Some probably allowed the globe to glow brightly, others only faintly, while some could not close the electrical gap at all.
- 5.2 The copper sulphate crystals were probably attracted to the charged strip A.
- 5.3 The crystals were also attracted to the charged strip B.
- 5.4 The liquid around the positive electrode probably turned brown.
- 5.5 You may have seen bubbles around the negative electrode. These bubbles are the gas hydrogen. How it gets there is a question you can answer only when you know some more chemistry.
- 5.6 The starch solution probably turned a dark blue-black colour. This colour change can be used as a test for iodine.
- 5.7 No iodine was present. If it had been there, the starch in the solution would have turned blue-black.
- 5.8 When the current was turned on the solution probably turned blue-black, indicating the presence of iodine.
- 5.9 A solution of potassium or sodium iodide is colourless. Therefore the iodide ion also must be colourless.
- 5.10 Potassium and sodium iodide crystals were probably both attracted to the two charged strips. This suggests that the crystals were uncharged.

TEST YOURSELF—OPTION 5

- 1 To find out if the solution is a conductor, the equipment described on page 74 may be used. If the globe lights, the solution is a conductor. (Remember that a solution may allow a small current through it, but the current may not be large enough to make the globe light.)
- 2 C
- A, B, D None of these will turn starch blue-black.
- 3 Electrode X. This is because the iodine, which turns the starch blue-black, is formed by the negative iodide ions losing their charges at the positive electrode and becoming iodine atoms (see pages 77 and 78).
- 4 C
- A, B Try holding your charged strips A and B close to some sodium iodide crystals. If both strips attract the crystals, then the crystals must be uncharged.
- 5 B
- A The iodide ion is discharged at the **positive** electrode, so it must be negative.
- C All ions are charged.
- 6 A

TEST YOURSELF—OPTION 6

- 1 B Captain Cook's voyages to Australia were made about 200 years ago. He first saw Australia in 1770.
- A Columbus discovered America in 1492.
- C Edison invented the light globe in 1879.
- D The first satellite was launched in 1957.
- There are clues in the option which enable you to relate the period in which the three scientists lived to the events mentioned in the question.
- 2 A
- 3 Discuss this with other students or a teacher. Did you think of the differences in speed of communication, the training of scientists and the places where scientists work?
- 4 Check with other students or a teacher.

NOTES

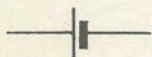
READINESS TEST

This is a test to help you find out what you know about electric circuits. You will need to know certain things about electric circuits to be able to do Options 2, 3, 4 and 5.

Answer the following questions on a page in your notebook.

Questions 1 to 3

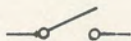
Special symbols are used when electric circuits are drawn. These symbols are used instead of ordinary diagrams to show the electric components of circuits. To answer each of questions 1 to 3, choose your answer from the seven symbols below and write the letter of the answer you choose.



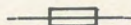
A



B



C



D



E



F



G

- 1 What is the symbol for an open switch?



- 2 What is the symbol for a globe?



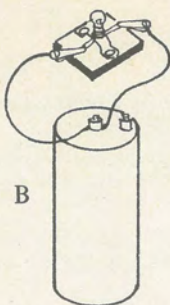
- 3 What is the symbol for a cell?



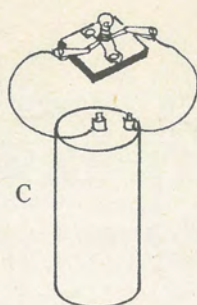
Questions 4 and 5 refer to the diagrams below.



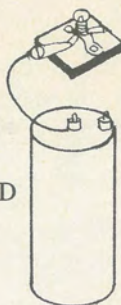
A



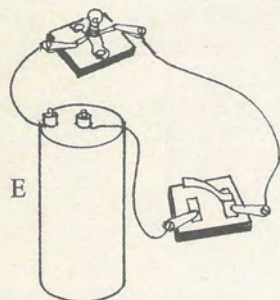
B



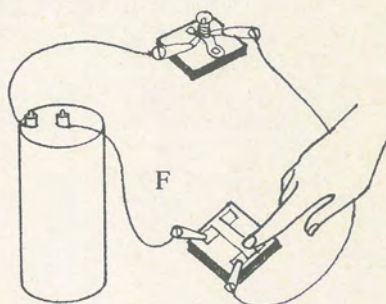
C



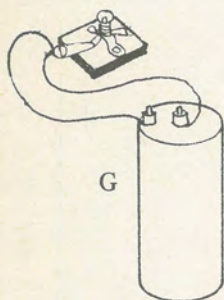
D



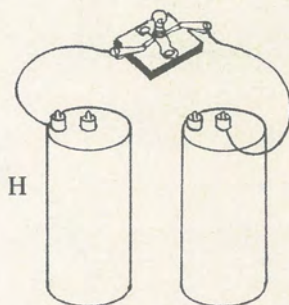
E



F



G



H

- 4 Write the letter of each diagram which shows an arrangement in which the globe will light.
- 5 Draw the electric circuit diagram for arrangement E.

Now turn to Check Your Answers—Readiness Test on the next page.

CHECK YOUR ANSWERS—READINESS TEST

1 C

2 E

- 3 A Did you choose G? This diagram shows 4 cells joined together to make a battery.

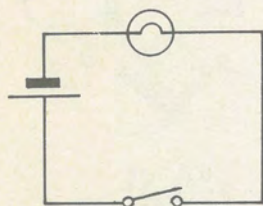
It is important for you to know these symbols. Make sure that you can draw the symbol for each electric component without having to look it up.

If you do not know how to strip the insulation from wires, or how to connect a switch, look at the ASEP film loop, *Stripping Wires*, which will show you how.

- 4 C, F For the globe to light, there must be an unbroken path (a closed circuit) from one terminal of the cell to the globe and back to the other terminal of the cell. If a switch is included in the circuit, then the switch must be closed.

If you chose any of the other diagrams, try out the arrangements they showed and check for yourself if the globe will light.

5



Many people were involved in the development and production of ASEP units.

As well as the ideas and suggestions contributed by ASEP staff members, valuable help was given by consultants, students and teachers throughout Australia during trials.

Members of the ASEP team associated with this unit included:

Writers: Jackie Lang (V) 1971-72
Malcolm Croxton (SA) 1973

Advisers: Les Dale (V) 1971-72
Jackie Lang (V) 1973

Test Writers: Barry Fraser (V) 1971-72
Juliet van Rijsbergen (V) 1973

Editors: Betty Gorrie (V) 1971-72
Patricia Sellar (V) 1973

Designer: Ray Smith (V) 1971-73

Artist: Ada Zull (V) 1971-73

Photographers: Brian Oakes (V) 1971-72
Bill Edmonds (V) 1973

BUSBY HIGH SCHOOL		
DATE	NAME	CLASS